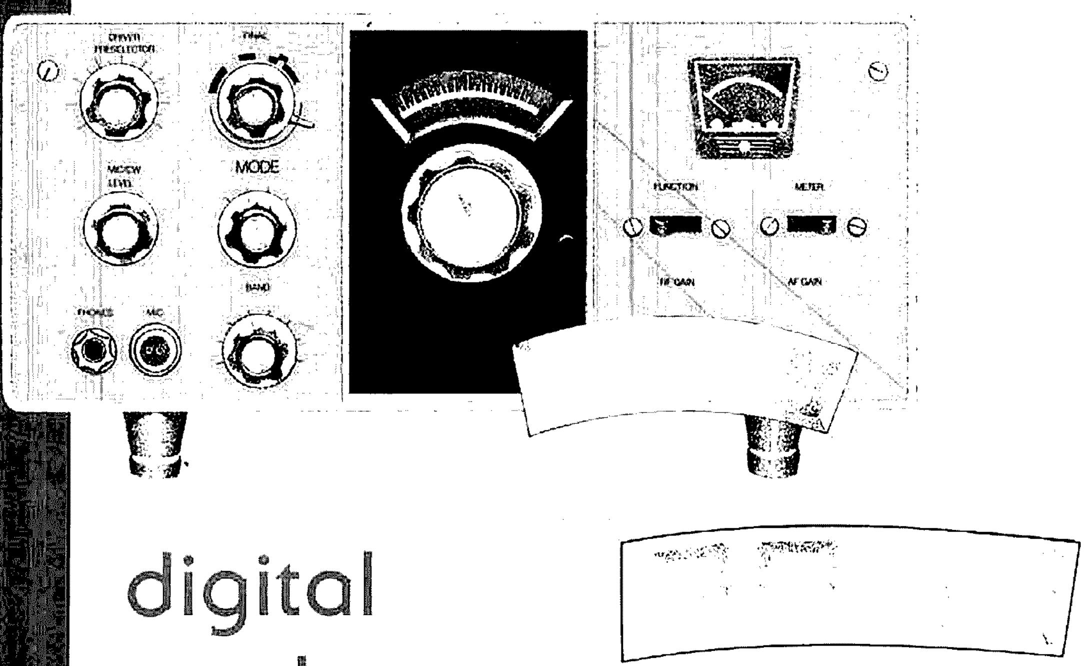
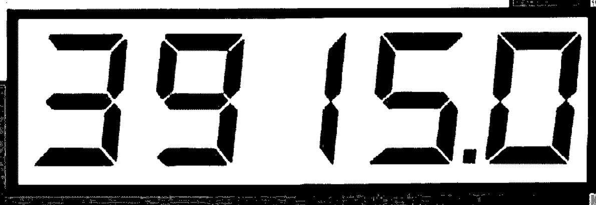
JANUARY 1987 / $2.50

ham radio magazine



digital readout

for the HW-101



focus on communications technology

ham radio
magazine

JANUARY 1987

volume 20, number 1

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00, three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service) one year, $37.00
All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

international subscription agents: page 114

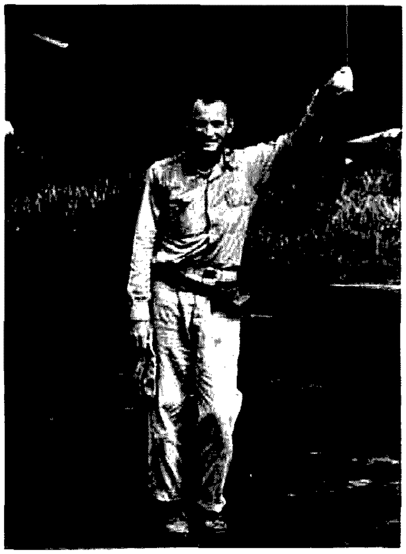
Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio* are available to the blind and physically handicapped from *Recorded Periodicals*, 919 Walnut Street, Philadelphia, Pennsylvania 19107

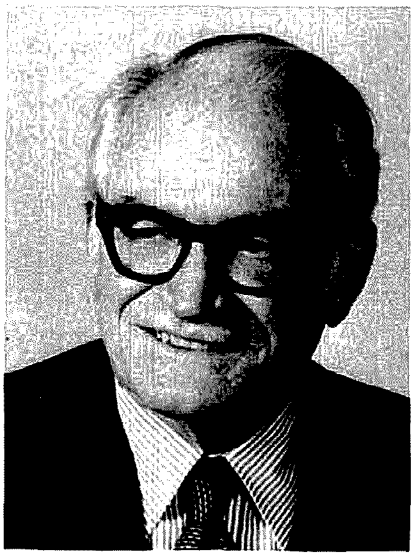
Second class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

**Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498**

contents



Amateur Radio's Retiree of The Year



There's a slim, funny book of cartoons making its way around the office these days. Titled, It's Time To Retire When. . .," it makes a case for retiring when . . . you start calling everybody "kids" . . . you hear yourself saying, "We already tried that and it didn't work" . . . more than half your income comes from winning sports pools . . . you tell "war stories" and the "kids" ask, "Which war?"

Now, we don't know much about retirement because the only one of us who's been around long enough to be retired has retired — and *un*retired — three times. But we do know that our readers and authors who claim to be retired seem to be just as busy and involved in the business of living as anybody else. Try getting them to answer the phone on a Tuesday afternoon. Forget it. They're out building something in the shop, tinkering with antennas, volunteering in community service, or traveling. Sometimes they're even starting new businesses or careers, packing two or three or four lifetimes into one.

We expect such will be the case with Barry Goldwater, K7UGA, Amateur Radio's unofficial Retiree of the Year. Moments before the 99th Congress concluded its work, he delivered a characteristically succinct farewell address, bringing his distinguished political career to a close with fewer than 100 words. His equally notable military career had come to an end in 1967, when, with the rank of Major General, he retired from the United States Air Force Reserve.

There aren't enough pages in this or any other magazine to begin to describe what this one man has done for Amateur Radio. Licensed as 6BPI in 1923 — and later, in the early 1960's, after a period of inactivity, as K7UGA — Goldwater has, over the years, been ham radio's indispensable ally on Capitol Hill. Besides working behind the scenes with integrity and finesse, he sponsored much enabling legislation, including that which led to the implementation of the VEC program and the ARRL/FCC Amateur Auxiliary.

During the Vietnam era, Goldwater's station, staffed by volunteers and operating around the clock, ran more than 240,000 phone patches from service personnel in Southeast Asia to families and friends back home. As the war wound down, RTTY replaced phone patches and 150,000 more messages were passed. Though Goldwater's busy schedule left little time for operating, his station manager — Tom Moore, W7FCQ, AFA6PU/AFF6C — told us that whenever the Senator was in town, particularly over the Christmas/New Year's recess, he'd frequently join the volunteers, often taking a full eight-hour shift.

The Senator's equipment, said to put many a broadcaster's station to shame, was based on a four-function Collins 208-U3 *transmitter*. A Collins 237B *rotatable log periodic* (6.5 to 30 MHz) with a 64-foot boom (longest element: 81 feet) was mounted on an 80-foot tower atop a hill 200 feet above ground, which was already some 2200 feet ASL. Traffic handling continued until January, 1983, when diminished activity in Southeast Asia allowed the station to be closed.

According to Tom Moore, most of the volunteers at K7UGA were retirees who "just wanted to help out." (Tom had a dual purpose: his son was a POW, and he joined the crew partly in hope of contacting him. Though they never connected through K7UGA, they were eventually reunited. Now retired, Tom still handles traffic from Southeast Asia, with 24,000 "Mom and Dad Morale" messages passed — an average of 500 per month — since the closing of K7UGA.)

Although we can't begin to do justice, in this small space, to Barry Goldwater's contributions to Amateur Radio, there is enough room to say a heartfelt "Thanks" and wish him all the best in his retirement. We'll be watching, with interest and appreciation, to see what he does next.

Dorothy Rosa, KA1LBO
Assistant Editor

It's Time To Retire When... is published by Ivory Tower Publishing Co., Inc., Watertown, Massachusetts.

packet board update

Dear HR:

A number of improvements have been made to the HAPN packet board described in our article, "A Packet Radio TNC for the IBM PC" [August, 1986, page 10]. Readers who have purchased, or plan to purchase, the bare board should be sure to follow the assembly instructions provided on the HAPN-1 diskette (ASSEMBLY.LST) rather than the instructions presented in the article. Otherwise, there's bound to be some confusion regarding the parts list and parts designations. Also, an oscilloscope is no longer required for setting up the board.

Jack Botner, VE3LNY
Hamilton and Area Packet Network

SSTV on the C64

Dear HR:

Thank you for publishing our article concerning receiving and transmitting SSTV via Commodore 64 without any external interface ["Get on SSTV — With the C64," October, 1986, page 2 43]. It is a great honor for us.

Copies of the complete machine language program, with two pages of instructions, are available on disk or cassette directly from us. Machine code means immediate transmission (the long delay to compose the picture affects only the BASIC version) and easy TX/RX functions; surely readers who have had problems in loading the published listings will be glad to know that.

I have never heard of the references Jim Grubbs, K9EI, mentioned in his translation of our article. They are not available in Italy. In the future we will try to surprise you with an article including some of the incredible software we are preparing.

On another topic, I was in the hell of Beirut in the Italian Army (United Nations contingent) and I have lots of pictures in my mind which cannot be forgotten. I very vividly remember the day which changed my life, when while patrolling in our tank, we were distracted by some gunfire and drove in the direction from which it came. We realized that a few U.S. Marines whose car was set on fire were defending their lives in a corner of a building. Maneuvering our tank and using it as shield, we succeeded in getting all of the marines into a safe position — or so we thought until seconds after, when I realized that one of them had been shot and was lying on the ground, still under fire. I immediately jumped out of our tank, and together with a brave Marine, among screams and shots, succeeded in getting that poor young man safely inside.

I remember nothing after that, since I had been shot myself and the world became black over me. Hospitals and re-education centers did not make the miracle; meanwhile I have lost my job and problems to the nervous system affect me. So thanks to the computers, I survive for the time being by writing articles and programs for magazines.

From time to time, a question comes to mind: was a medal and some words spoken in a speech by a Prime Minister worth so many problems and pain? Well, no matter — the true recompense is knowing that the life of a man was saved.

The name of the spring which pulled me out of my secure tank was simply altruism and solidarity, qualities common among us Amateur Radio operators. Would I do it again? Certainly, *yes* — though possibly in a less instinctive way.

Giuseppe Cameroni, I2CAB
Vigevano, Italy

should VEs issue callsigns?

Dear HR:

I propose that the FCC end the waiting period for previously unlicensed applicants (i.e., those who had no prior callsign) who pass VE examinations.

The FCC would issue random blocks of 2x3 callsigns to VECs in unmarked envelopes. The VECs would not be *issuing* the calls (the FCC does that); they would merely be *distributing* the callsigns to successful applicants at each test session, acting on the FCC's behalf just as they're doing when they administer Amateur radio exams.

The expiration date of each call would be ten years after the date of the examination. New Amateurs who didn't like their new calls could simply send in a form 610 and request a callsign change.

As soon as applicants received their callsigns, they could get on the air and enjoy their new privileges immediately. The FCC could still cancel the licenses of any newly-licensed Amateurs found in violation of FCC rules.

The FCC could use their existing sealed-envelope technology for distributing callsigns to the VECs. The VE group would then request a specific number of callsigns for their test session and pass the callsigns out to successful applicants.

Each callsign — known only to the FCC until the envelope is opened — would be printed on the license form. The VE would add the successful applicant's name and address and the expiration date of the license, giving one copy to the new licensee and sending another to the FCC for processing.

It's interesting to note that there's no waiting period when you get your driver's license. You get your license and drive off. When you pass an Amatuer Radio exam, you should be able to get your license, go home, and use those new privileges right away.

Conrad Ekstrom, WB1GXM
Claremont, New Hampshire 03743

a true-frequency digital readout for the HW-101

Try this simple mod for more precise tuning

If you've ever operated an HW-101, you know how frustrating it can be to try to tune it to a specific frequency; the main tuning dial simply isn't precise enough. In an effort to solve the problem, I decided to add a digital readout to my rig.

I didn't really want to *build* one; I just wanted to find an old SB-650 Digital Frequency Display, the Heathkit readout designed to accompany its HW- and SB- series equipment. But I couldn't find one for sale locally, and Heath had long ago sold out its final inventory. I decided to go ahead on my own. I tried to get a copy of the SB-650 manual, but Heath had no more.

Why this seeming obsession with the SB-650? In order to develop a reading from an HW-101, all three transceiver oscillators must be sampled and multiplexed into the counter section in proper sequence. The counting circuitry itself is more or less standard, but the multiplexing circuit is the key to success. I knew that Heath's circuit worked, and the gating and logic tables I came up with looked too unwieldy to be correct.

Photo A. The top, bottom, and digit boards (left to right), are shown interconnected and ready for mounting.

Although Heath couldn't provide a manual, the company did supply several schematics of the multiplexing and time chain circuitry. The multiplexing used in my readout more or less duplicates the Heath circuit.

theory of operation

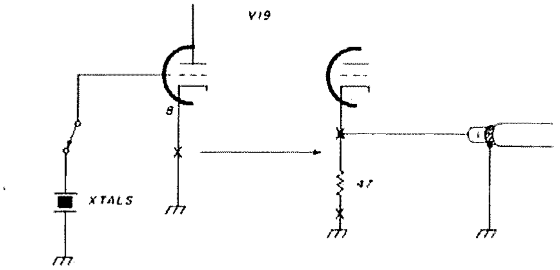
A transceiver digital readout is basically a frequency counter preceded by processing circuits that allow proper sampling of the circuits in the transceiver that determine the final operating frequency. In the HW-101 the operating frequency is determined by heterodyne action among three oscillators. The heterodyne oscillator is a high-frequency oscillator, while the carrier and VFO oscillators are relatively low in frequency. Both the carrier and VFO frequencies are essentially *subtracted* from the higher-frequency heterodyne oscillator frequency to establish the operating frequency. The processing circuitry of the readout first enters the highest frequency into the counters, then subtracts, one at a time, the other two oscillator frequencies from it. The true operating frequency is then presented to the digital display through the latches. (Although the "addition" and "subtraction" mixing takes place in different stages of the transceiver for Transmit than for Receive, the same oscillators ultimately perform the same job. Thus by tapping the oscillator outputs, the readout is accurate to within 100 Hz $\pm$ clock error, and reads the same frequency in either send or receive mode.)

system flow

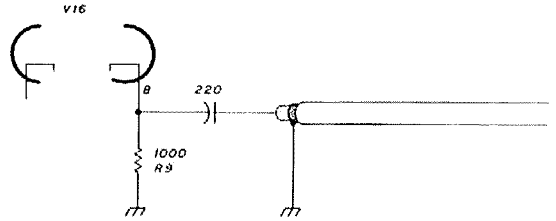
In the transceiver, samples of the three oscillators are connected by coax to phono jacks added to the back of the transceiver chassis. These are connected by 36-inch phono cables to three input phono jacks on the back of the readout chassis. (See **fig. 1** for transceiver sampling hookups.)

Each jack connects to an input stage consisting of a 40673 MOSFET preamp and a 2SC945 (or 276-2016) pulse-shaper circuit. After passing through buffer gates in U1 and being divided by four in frequency in flip-flop

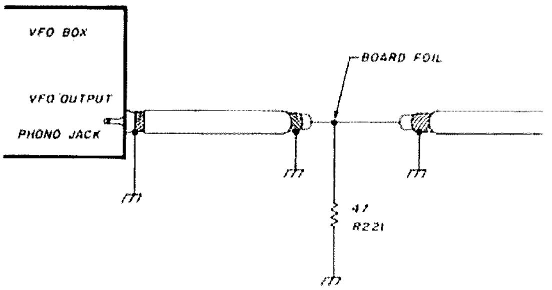
By **Ed Murdoch, NU4F**, Route 1, Box 238, Omega, Georgia 31775



Heterodyne Oscillator: bandpass board, Tube V19, Pin 8 (cathode). This cathode is normally grounded. Break foil at X, solder 47Ω watt resistor across break. Connect center of coax to tube pin side, shield to adjacent foil ground. Coax goes to phono jack on rear of chassis.



Carrier Oscillator: modulator board, Tube V16, pin 8 (cathodes). This point also connects to other cathode of V16. These are already above ground with appropriate RF voltage. Coax is coupled to pin 8 foil through 220 pF capacitor.



VFO: bandpass circuit board. Sampling coax connects to point on board where output coax of tube V20 connects. Connect coax center conductor to the foil point adjacent to high side of R221 (47 ohms).

fig. 1. Transceiver sampling connections (all connections made to underside of board). Each length of coax goes to a phono jack installed on the back of the transceiver chassis. Regular 36-inch shielded phono cables connect to digital readout.

U2, these three circuits are gated sequentially into the Least Significant Digit (LSD) counter, U17, by multiplexer chips U3, U4, and U13 through U15. The gating pulses for *enable* and *inhibit* are developed from the timing chain combination of oscillator-buffer-feedback gates U5, divide-by-four flip-flop U6, and time-division decade counters U7 through U12. The reset pulses for pulse counters U17 through U22 come from U15, pin 3. The reset pulses for divide-by-four flip-flop U2 come from U16, pin 6. The transfer pulses for the latches come from U16, pin 3.

In order to feed the correct oscillator signal to the counters at the proper time, a time frame of four intervals is established. This is done by gating several combinations of outputs from U10, U11, and U12 in the timing chain. These in turn are interlocked by other gates to allow each oscillator to be counted once per frame and

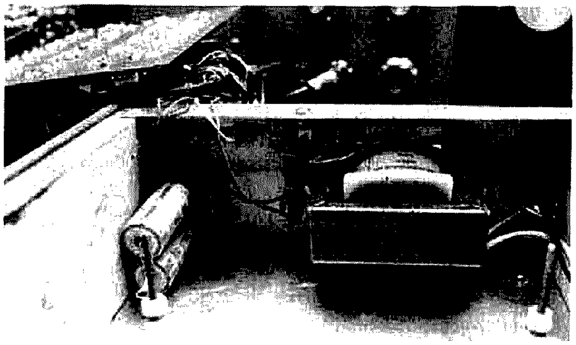


Photo B. Power supply components are mounted on rear chassis wall.

shifted to the up count (add) or the down count (subtract), as is appropriate. The fourth interval is used for pulse development by the RC network connected between U13, pin 8 and ground. After both reset pulses and the transfer pulse have been established, the next clock pulse starts the cycle again.

The counting section, which consists of a cascaded series of six 74LS192 up/down decade counters (with one counter for each display digit), provides a frequency divided-by-ten output to the following counter and its parallel output to its own digit decoder in binary-coded decimal (1-2-4-8, also referred to as ABCD in the accompanying figures). Therefore each counter has what it needs to produce the correct reading for its own LED digit, which it feeds to the digit by way of a 74LS75 latch. The divided-by-ten output is then passed on to the next counter chip, which acts in a similar fashion.

Each storage latch holds the previously transmitted number until the transfer pulse occurs, causing the latches to accept the newest measurement offered by their respective counter's ABCD outputs. Each of these "updates" is caused by a combination of reset pulses to the various flip-flops and counters so that each new count is synchronized. The latches feed the ABCD data to the input lines of their respective 74LS47 BCD to seven-segment decoder/drivers, which decode the ABCD numbers and provide the drive for the correct segments of the seven-segment display digit.

Overall synchronization is established by a master clock oscillator from which the various pulses, time intervals, and switching sequences are derived. The time occurrence of the individual gating pulses is also determined by frequency division (by divide-by-four flip-flops 74LS73, and by divide-by-ten and divide-by-two counters 74LS90). The clock frequency of 1 MHz was chosen to make frequency-division factors easily obtainable.

construction

The circuits were planned on quad paper and then built up on two 4 1/2 x 6 5/8-inch circuit boards and one 2 3/4 x 3 3/4-inch board (**Photo A**). The two large

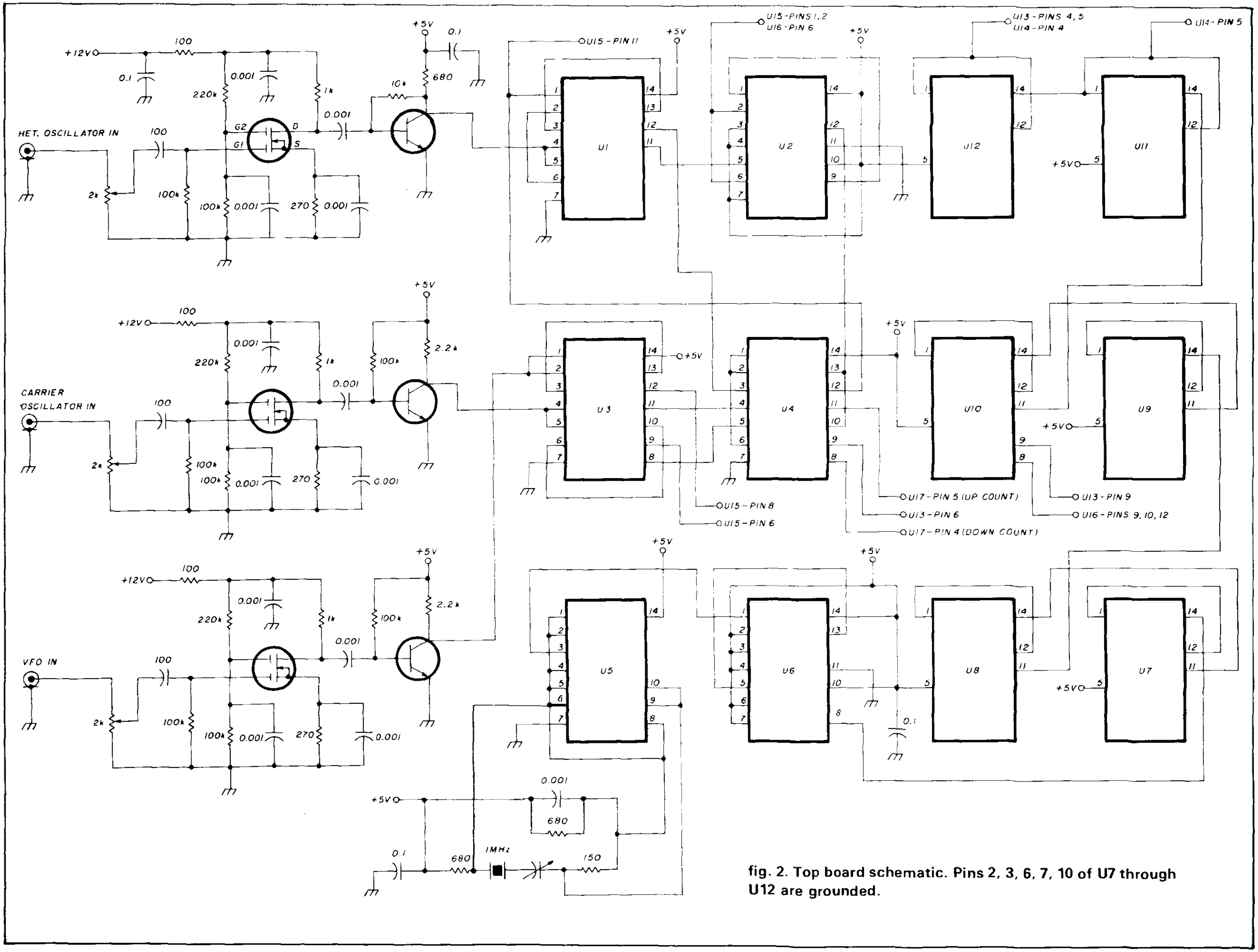


fig. 2. Top board schematic. Pins 2, 3, 6, 7, 10 of U7 through U12 are grounded.

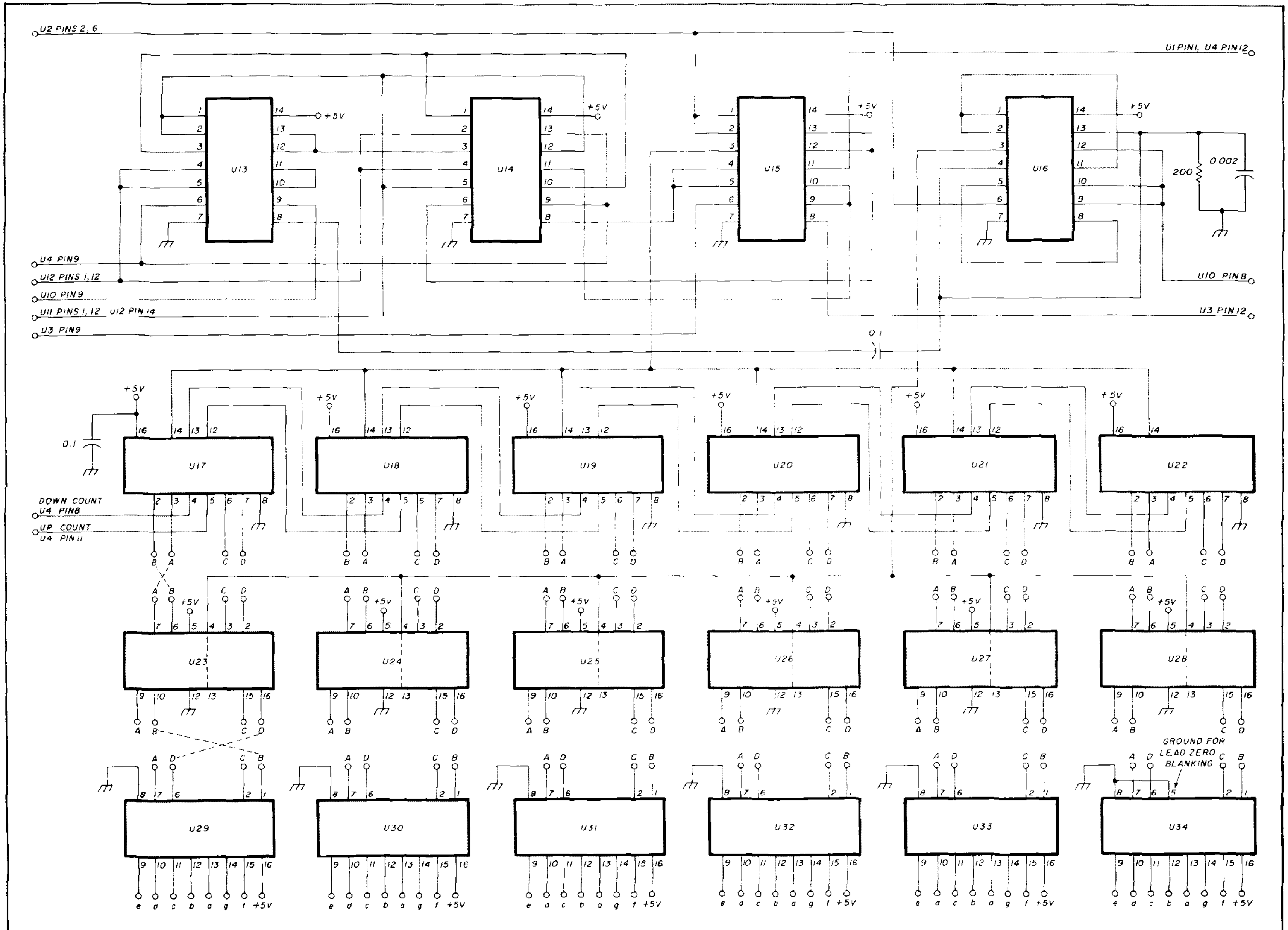


fig. 3. Bottom board schematic.

Table 1. Parts list. Cost of project should be approximately $85.00.

40673 MOSFETs	MHz Electronics*
2SC945 Transistor	Radio Shack 276-2051 or 276-2016 or MPS 3904
U1,U3,U4,U5	74LS00 QuadNand Gates**
U2,U6	74LS73 Dual J-K flip-flops**
U7-U12	74LS90 Decade (bi-quinary) counters**
U17-U22	74LS192 up/down decade counters†
U23-U28	74LS75 Quad latch**
U29-U34	74LS47 BCD/seven-segment decoder/driver**
0.3-inch seven-segment digit display	Radio Shack 276-053 (common anode)
Chassis	No. EDCH-288†
Top and bottom boards	Radio Shack 276-147

*MHz Electronics, 2111 West Camelback Road, Phoenix, Arizona 85015.
**DoKay Electronics, 2100 De La Cruz Boulevard, Santa Clara, California 95050.
†All Electronics, P.O. Box 20406, Los Angeles, California 90006.

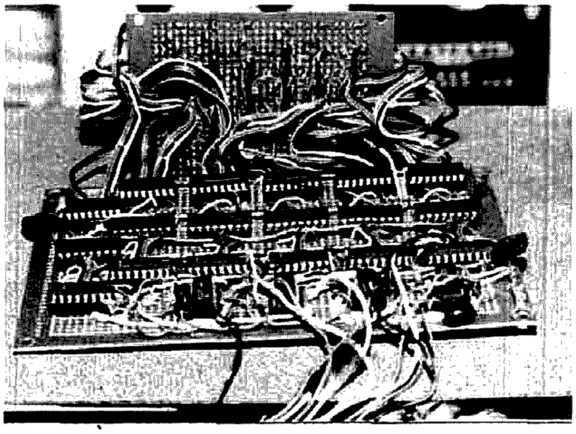


Photo D. A closer view of the bottom and digit boards illustrates interconnections.

boards are mounted upside-down in the chassis and separated by spacers. The top board contains the input wave shaping circuits, the timing chain, and part of the multiplex circuitry. The bottom board contains the remainder of the multiplex circuitry, the counters, latches, and decoder/drivers. The outputs of the decoder/drivers are cabled to their respective segment dropping resistors mounted on the third board, which also holds the digits. This board is at right angles to the other boards. A window is cut in the chassis front to accommodate the digits.

The power supply parts are mounted on the rear wall of the chassis. So are the three input jacks. Prototype wiring is shown in **Photo B**; the input wiring was later changed to coax.

building the chassis

The first step is to determine the location of each part. Next, mark off and drill the mounting holes for the input phono jacks, the fuse holder, and front panel switch. Then drill the transformer and heat-sink-regulator mounting holes, tie-point holes, and holes in the chassis top for the circuit board bolts.

With an awl, mark guidelines for cutting the digit window. Drill holes in diagonally opposite corners of the outline to accommodate the sabre saw blade and cut the rough opening. *This is a tricky and possibly dangerous step, so I'd suggest you secure the chasiss firmly in a vise while you make the cut.* Stay slightly to the inside of the guidelines; use a small, flat file to smooth the edge of the opening to its finished size. For the window its self, I cut a piece of clear plastic (box covers are ideal) and glued it into place.

Photo A also shows the approximate board locations of all parts and wiring paths for the multiplexer interconnections. Other wiring shown in the remaining figures according to normal schematic drafting practice.

the power supply

The power supply (**fig. 5**) is typical of so-called "economy" supplies in that a single secondary winding is used to develop two voltage levels. (The MOSFETs need 12 volts; the rest uses 5 volts. Both are regulated.) The transformer supplies 18 volts ac through a bridge rectifier to the filter for the 12-volt section, regulated by a 12-volt Zener diode; a center tap provides 9 volts ac to the filter of the 7805 5-volt regulator.

The power supply components, installed on the back of the chassis, are partially supported by tie points. The 7805 regulator is mounted on a standard T-220 type heat sink positioned directly against the chassis for improved heat removal. With the circuit boards in place, it's a pretty close fit; I blew out a bridge rectifier and the fuse by not watching a test probe closely enough while making tests. I have now covered exposed terminals with a tape wrap.

circuit boards

The digit display board (**fig. 4** and **Photo C**) contains the six LED digits, sockets, and 42 1/2-watt 330-ohm dropping resistors — one resistor per digit segment. This board should be wired first. Note that this is the only place wire-wrap sockets are used. This is because I planned to support the digit board against the chassis front by its cable pressure and put several turns on each pin for extra stability. I made a seven-wire color-coded combination for each digit: a four-wire section plus a three-wire section.

After making all cable solder connections, cut off all

the pins except the 5-volt supply pins to about 1/4 inch, leave these longer (about 1/2 inch) so that the 5-volt bus can be run straight across.

There are no grounds on the digit board. Each segment "grounds" through its driver connection when activated; these are common anode devices.

The two decimal point positions are grounded through 330-ohm resistors over to the front ground bus on the bottom board. These decimal points divide the six digits into MHz and KHz separations.

the bottom board

The bottom board contains multiplexer chips U13 through U16, decade counters U17 through U22, latches U23-U28, and decoder/driver chips U29 through U34, plus sockets (**Photo D**).

You'll have to offset three chips to fit all the parts on the board, but this poses no problem. In fact, it actually helps; because the column of offset chips represents the most-significant-digit position, you'll have a handy reference point to which you can refer as you add parts to the board.

Photo E shows the location of the two ground buses,

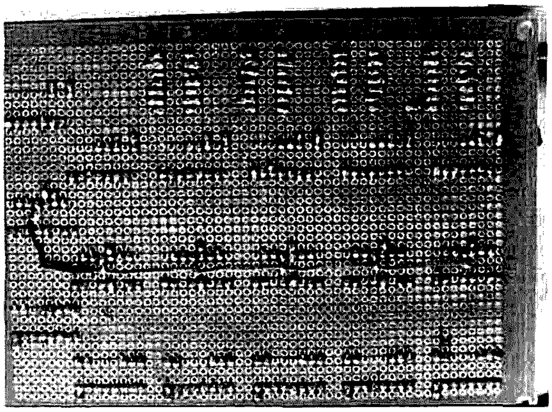


Photo E. Rear view of bottom board shows closeness of solder points and bus for latches that transfer pulse feed.

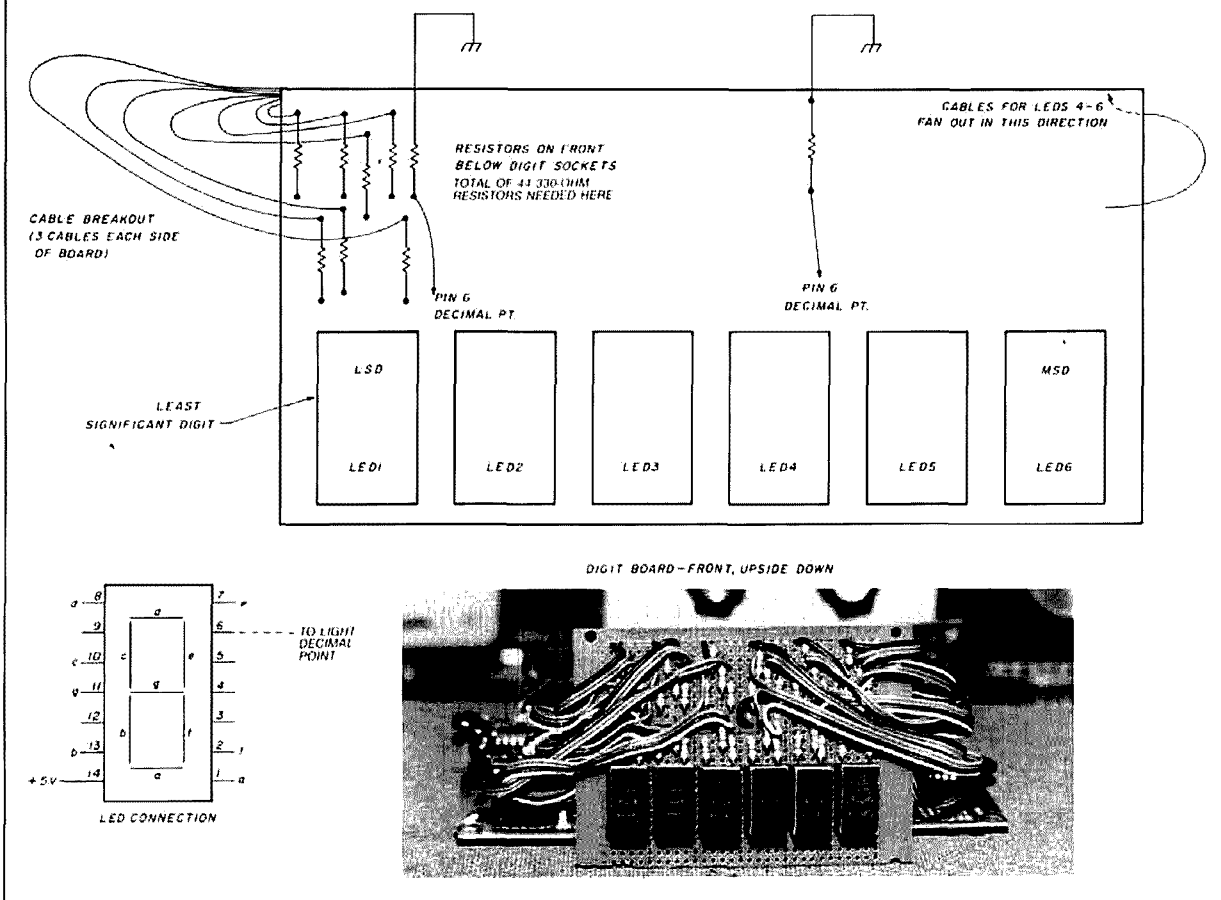


fig. 4. Digit board. Outputs of decoder/drivers are cabled to their respective segment dropping resistors. One cable section per digit goes to corresponding decoder on bottom board. Seven 330-ohm resistors per digit — except for LEDs No. 1 and No. 4, which have a resistor going from pin 6 to ground.

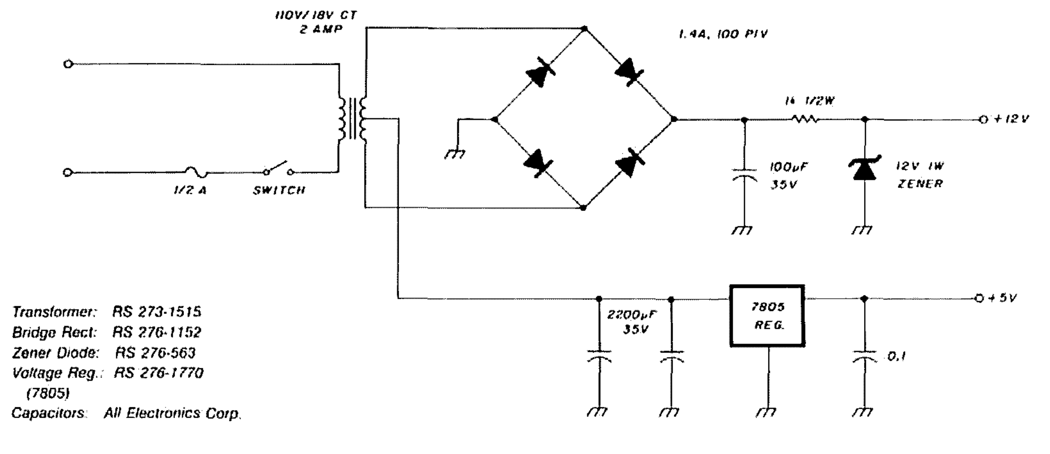


fig. 5. Power supply schematic.

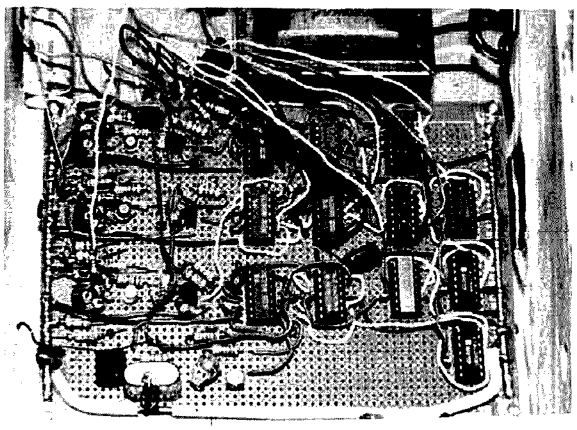


Photo F. Clock oscillator has prominent location in lower left corner of top board view.

made from No. 12 wire and secured by lugs to the board mounting bolts. (While not an ideal ground, it works.) The photo also illustrates the closeness of the solder points on the pins. This was the part of the whole project that most concerned me. I tried to cut each wire so that after inserting it through the top of the board there would be just the right amount of bare wire left to bend over flat against the pin and spin around with a wiring tool so that no further wire cutting would be necessary. I'd crimp it slightly with my long-nose pliers to assure a tight fit and then solder very carefully. In the counter section of the board I soldered corresponding wires or corresponding cabled ABCD data runs. Then I verified both continuity and the absence of adjacent pin shorts before continuing. This approach paid off. I found two adjacent pin shorts and one cold solder joint that I fixed immediately, saving years of anguish. As I went along I also aligned any bent pins.

In this same photo you can see a bus running under the center line of the latch sockets. This bus carries the transfer pulse to pins 4 and 13 of each latch, which are connected together on the bottom of the board (shown by dotted lines in **fig. X**). There simply wasn't room for this run on the top side.

Because the local Radio Shack was out of small 0.1-pF tantalum capacitors, I used their larger, standard PC-type for transient bypass and fitted them as best I could.

Most of the wiring of the multiplexer chips — on both bottom board and top board — is in the form of interconnection of gates in the same chip or in other multiplexer chips. On the bottom board I started at pin 1 on the top left side of chip U13 and went numerically pin-by-pin, finishing out each chip before going to the next. I made a color-coded tabulation of the off-board wires, leaving these about six inches long for later connection to the top board.

top board

The top board (**fig. 2** and **Photo** F) contains the input preamp/pulse-shaper circuits, the clock oscillator U5, and associated time-division chips U6 through U12, as well as multiplexer chips U1 through U4.

Friends, I didn't know how many of life's simple pleasures I'd missed until I started working on the top board. As with the other board, I determined the layout on a board-size piece of quad paper. In an attempt to keep the input wires short, I crowded the preamp stages. Besides giving the whole thing the look of last year's campfire, it began to look as if I might have an interstage coupling problem on my hands. Actually, the only place such coupling ever did occur was between the wires from the input jacks. After I no longer had to remove the top board for anything, I changed these to coax.

I installed the 40673 preamp and 2SC945 pulse shaper circuits first, using 1/8-watt trim pots as the input impedance for each preamp, but I just tacked on the wires from the input jacks. I expected to have to experiment with the resistance to get it in the right range for the input circuits. (The samples from the transceiver have to develop a voltage across a load at their respective input stages to apply to the MOSFET gate inputs. There is a limit as to the amount of current flow through this load. The optimum resistance worked out to be about 2 k (which is the input impedance listed on the spec sheet for the SB-650).

Radio Shack couldn't help with 2-k pots, so I replaced the original 1-k units with 5-k, 1/2-watt trim pots, paralleled with a 3.3-k resistor under the board. This arrangement works perfectly. (**Figure 4** shows only a 2-k variable resistance.)

Though the 40673 ***MOSFET*** circuit is similar to that used in the SB-650, I first saw it in an article in *QST*.[1] The crystal clock oscillator design was also taken from this article.

The components of the 2SC945 pulse-shaping circuits were determined by experiment because I couldn't find any characteristics curves to determine the proper parameters for saturation.

Rather than worry about socket contact resistance and corrosion, I direct-wired the transistors. To minimize the danger of static blowout of the MOSFETs, I borrowed a dc-operated isolation-type iron from Bobby Hobby, KA4DPF, the friend who took the photo for this article.

Next I wired the clock oscillator, which was almost a vacation by comparison. I then mounted all the sockets for the IC chips. I wired miltiplexer chips U1 through U4 and the oscillator chip, U5, first. I followed the same wiring scheme on this multiplexer section as on the bottom board (starting at pin 1, upper left, etc.).

Then I wired time-division chips U6 through U12. Except for the divide-by-four flip-flop U6, the wiring almost duplicates itself from chip to chip. Chips U7 through U12 require that pins 2, 3, 6, 7, and 10 all be grounded. To prevent chaos, I first connected these pins on each chip together on the underside of the board, then connected them to a ground bus. I had to use a little spaghetti here and there to avoid other pins.

final assembly

Connecting the digit board to the bottom board is the first step in the final assembly.

Figure 4 shows a section of seven-conductor cable going to each digit resistor area. The cable is split into two sections each to allow for more flexibility in positioning the board against the window. Using the color coding of the various wires, I tabulated a wiring plan that made it quick and easy to connect the cable ends to the proper pins on the decoder/driver sockets. When I first planned this arrangement I was concerned that the digit board might not be secure enough without direct mounting on the chassis. Not to worry — you couldn't knock it loose with a baseball bat. Finally I connected those almost-forgotten off-board wires from the bottom board to their top-board destinations.

The main boards are mounted on four 1 1/2-inch, 6/32 bolts protruding downward from the top of the chassis (viewed in normal operating position). A 3/8-inch nylon spacer on each bolt separates the chassis from the bottom board, which is secured with washers and nuts. (The ground lead from the 2200 μF filter combination connects to a lug at the nearest bolt.) Three-quarter-inch aluminum spacers on the bolts support the top board, which is secured by nuts. Lugs carrying the top board ground buses go under these nuts.

adjustments and calibration

Proper sampling levels are adjusted by placing the transceiver on the 29.5-MHz band, in the receive mode, and adjusting the three input trim pots to just slightly more than the level needed to cause a 29.5^{5} MHz reading to lock on the display.

First I adjusted the 1-MHz clock oscillator trimmer to zero beat with WWV, using a portable receiver loosely coupled to the oscillator gate section by an insulated wire wrapped around the receiver's telescope antenna. Even with the economy-type trimmer the frequency stays within a few Hz after several hours of warmup, varying no more than about 100 Hz after 24 hours of continuous operation.

With the trim pots set at minimum, I switched the transceiver to the 29-MHz range; the heterodyne oscillator is at its highest frequency here, and losses through the sampling circuitry are greatest. (In other words, if it works here it should work anywhere.) At this point the display read all zeros, as was appropriate. Then I advanced the heterodyne oscillator trim pot until a firm reading in the region of 38 MHz was showing (this is the frequency of the heterodyne oscillator crystal on this band).

Then I adjusted the carrier oscillator trim pot for a marked drop in frequency reading, to about 34 + MHz; I adjusted the VFO trim pot for a further drop to 29 + MHz. I advanced each trim pot slightly and closed up the chassis.

Naturally the first thing I did was to tune down to 7335.0 USB. As I brought up the audio gain, I heard, with perfect clarity, "This is CHU, Canada. The time is . . ." — one of the sweetest sounds I have ever heard.

This readout can be adapted to some other rigs. By using the heterodyne oscillator input only, it can be used for low-voltage level frequency counting, with 100-Hz resolution.

If you have any questions, write (please enclose SASE) and I'll try to help.

reference

1. Philip S. Rand, W1DBM, "The BEEPER: An Audible Frequency Readout for the Blind Amateur," *QST*, September, 1983, page 19.

ham radio

2.3-GHz prescaler

Extend your digital counter's dynamic range

Some years ago, I built a prescaler for my rf frequency counter which extended its operating range from 550 MHz to above 1300 MHz.[1] While this prescaler provided a means of measuring the frequency of 1296-MHz equipment accurately, it was never easy to use because of its limited input sensitivity.

Recently I built a prescaler for my present counter which virtually eliminates most of the shortcomings of that earlier model. This prescaler is based on a divide-by-two integrated circuit, the Telefunken U822, which operates well beyond 2000 MHz. Unlike my earlier design, this prescaler incorporates a preamplifier to increase the useful dynamic range so that the input signal level does not need to be closely controlled.

circuit development

The U822 is a low-cost silicon monolythic IC designed for the consumer market in such applications as cable TV tuners and satellite TV downconverters. Packaged in a four-lead plastic housing similar to those used for low-cost RF transistors such as the MRF901, the U822 operates from several hundred MHz up to at least 2.0 GHz and produces a low-level output at one-half the input frequency. A similar device, the U824, is useful as a prescaler for 600-MHz counters and electrically quite similar to the U822. The only major difference between the two is that the U824 divides by four rather than two. Although this article describes the U822, the U824 can be installed in its place without circuit changes if a divide-by-four prescaler is desired.

dynamic range limitations

One problem with using the U822 to extend the operating frequency range of a digital counter is that the input power range (dynamic range) of the divider is quite limited. This means that the power level of the input signal must be held within close limits. If this is not done, the divider may not produce an output — or worse, it may produce a spurious output not at the correct frequency.

Generally the signals we wish to measure with a frequency counter aren't available at an optimum power level. Therefore it's more than a small nuisance to have to deal with the limited dynamic range of a divider in a prescaler used as a piece of test equipment. One solution to this problem is to increase the dynamic range of the prescaler. Then, we can be more confident that the output frequency is at exactly half the input frequency, and we'll be able to use the prescaler for a wide range of signal power levels.

limiting amplifier

One good way to increase the dynamic range of the prescaler is to place a limiting amplifier ahead of the divider. A limiting amplifier provides a constant output power over its entire input power range. Of course, all real amplifiers are limiting amplifiers in some sense, because there's a limit to their output power, but we usually don't try to operate them this way. The key point is this: a limiting amplifier will compress the dynamic range of the input signal to a much narrower output range, and this narrower output power range can be more suitable for the input of the digital divider. The question now is, what is the "suitable" range for the U822?

The data sheet for the U822 lists a minimum input signal power and frequency over which the divider is guaranteed to function properly. The input signal level must be greater than 150 millivolts RMS, and the divider will operate to a minimum of 2000 MHz. The maximum input signal power for operation isn't listed, but the maximum survival power (higher power may damage the device) is listed. In addition, the data sheet doesn't provide operational data on "typical" devices nor on operation *above* 2000 MHz. So, to design a limiting amplifier input for the prescaler, we need more detailed information on how the divider performs over a wide range of input power levels, and at various frequencies.

By **Jerry Hinshaw, N6JH**, 142 Kensington Place, Frederick, Maryland 21701

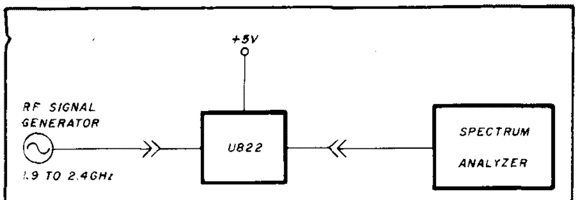


fig. 1. Test setup used to measure the operating range of the divider.

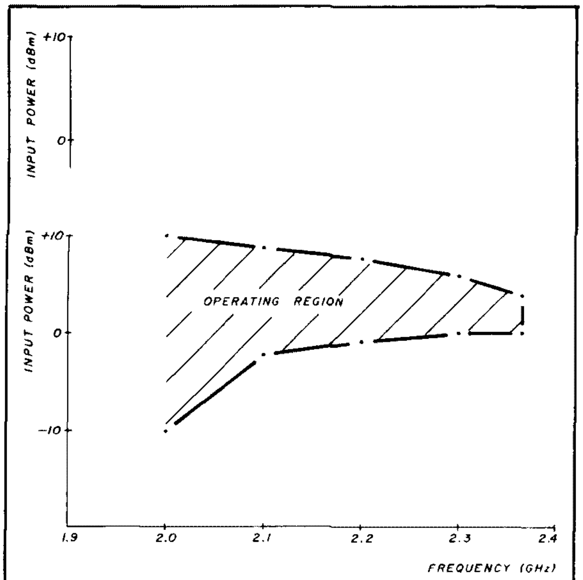


fig. 2. Operating range for the U822. RF inputs outside the shaded area produced unpredictable outputs.

tests determine operating range

To get this data, a U822 divider was tested using the setup shown in **fig.** 1. The input frequency and power level were adjusted while the output signal frequency was monitored using a spectrum analyzer. (The spectral display gives a more sensitive indication of when the divider is beginning to malfunction than does a frequency counter. This is because the spectrum analyzer shows when the divider output signal starts to break up or develop nonharmonic spurious products more quickly than these problems would appear on a digital counter display.) The divider was monitored from about 1800 MHz, where it has a fairly wide dynamic range, to about 2400 MHz, where the operating range is very narrow. The results of these measurements are plotted graphically in **fig. 2**. The supply voltage to the U822 was held constant at 5.0 volts for these measurements. It is probable that by carefully tuning the supply voltage slightly over the range of 4.8 to 5.2 volts, the maximum operating frequency could be increased. However, it's clear that we're near the limits of the device already, and further tuning would probably yield only marginal improvements.

U822 operating parameters

Figure 2 clearly shows that the maximum and minimum input power limits converge to a point at which only one unique power level can produce a reliable output signal from the divider. Pilots call such a region in a flight performance curve the "coffin corner;" although the consequences for us are fortunately not fatal, the convergence does indicate the practical limit for the device. To the left of this limit is the operating range, and the "window" of permissible powers increases rapidly as the input frequency is reduced. Also, we can see by inspection of the curve that a power level of + 5 dBm will provide satisfactory operation to above 2300 MHz. This information on the operating power ranges of the divider is what's needed to design a limiting preamplifier for the prescaler.

Figure 2 also shows the minimum signal level needed to deliver good divide-by-two outputs. The required level ran from − 12 dBm at 1800 MHz up to the + 5 dBm intersection at 2400 MHz. Thus, the dynamic range of the input decreases from 20 dB at 1800 MHz to 11 dB at 2100 MHz, down to only 6 dB at 2300 MHz. This means that to measure the frequency of an unknown signal, its power would have to fall within this narrowing region. If a limiting preamplifier stage were placed in front of the divider, the operating dynamic range could be increased both above and below the limits of the divider alone.

preamplifier design

By testing a U822 divider, I discovered that the desired preamplifier should provide ample gain up to at least 2400 MHz and should have an output power limit of about + 5 dBm. Naturally, it also would be nice to have wide bandwidth, low cost, small size and low power drain. Such a list of requirements would have been difficult to satisfy a few years ago, but monolythic silicon rf amplifiers that provide nearly all of these desired attributes are now available. They're small, have very wide bandwidth, and are less expensive than most low-noise rf transistors. Because they draw a fair amount of current, they do fall a bit short of our ideal, but only in terms of power drain. These "monolythic microwave integrated circuits" (MMICs) have been described recently in Amateur publications[2,3] and are available from stock at a number of distributors.

the MMIC

The MMICs described in References 2 and 3 are available from the manufacturer, Avantek, in four types. The data sheets for these devices list a number of operating characteristics, including the 1-dB compression point, which is the output power level where the gain has been reduced by 1 dB from the small-signal value. This com-

pression point information is what we need to choose a device to limit near the +5dBm point, which the U822 divider requires for best operation. In fact, the MMIC data sheets contain curves of output compression point versus bias current, which can help us choose an operating point most appropriate for this application.

Of the four devices, the MSA03 seems best suited for use as the prescaler amplifier because it has an output compression point of about +5 dBm at 2000 MHz when operated at 25 to 30 mA bias. This compression point decreases with frequency, which matches the U822 operating window even better than if the compressed power level remained constant as the signal frequency increased. An MSA03 amplifier was assembled and tested for compressed power; the results are shown in **fig. 3**.

In addition to compressing input signals to the constant output power required at the U822 divider's input, the MMIC amplifier also provides gain to small signals, which would otherwise be below the operating range of the divider. Thus, if the preamplifier does its job properly, the dynamic range of the prescaler will be extended at both ends. The MSA03 will provide about 12-dB gain to small signals so that the bottom of the curve in **fig. 2** should be lowered by about this much. The top end of the curve will also be raised, but there's a limit to how high it can go; the MSA03 amplifier itself has a "never exceed" input power specification of 100 mW. Thus, with just one stage of amplification using the MSA03 we can expect a greater than 20-dB increase in dynamic range, which is enough to transform what otherwise would be a temperamental prescaler into a useful test device.

The output power level from the U822 is about −20 dBm when driving 50 ohms. If this level isn't sufficient to drive the frequency counter, a second MSA amplifier could be installed on the same board following the divider to increase the output power. A single MSA03 will bring the divider's output up to at least −8 dBm (90 mV RMS), which should drive all but the least sensitive frequency counters.

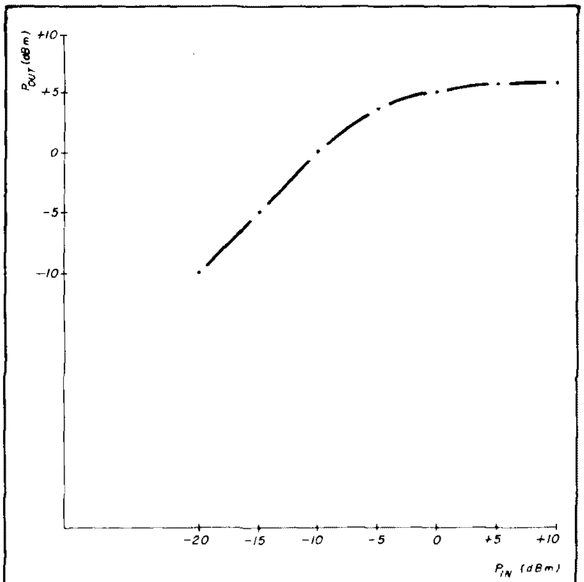


fig. 3. P_{OUT} vs. P_{IN} for the MSA03 at 2.0 GHz, 25-mA bias. The amplifier shows the expected limiting near +5 dBm.

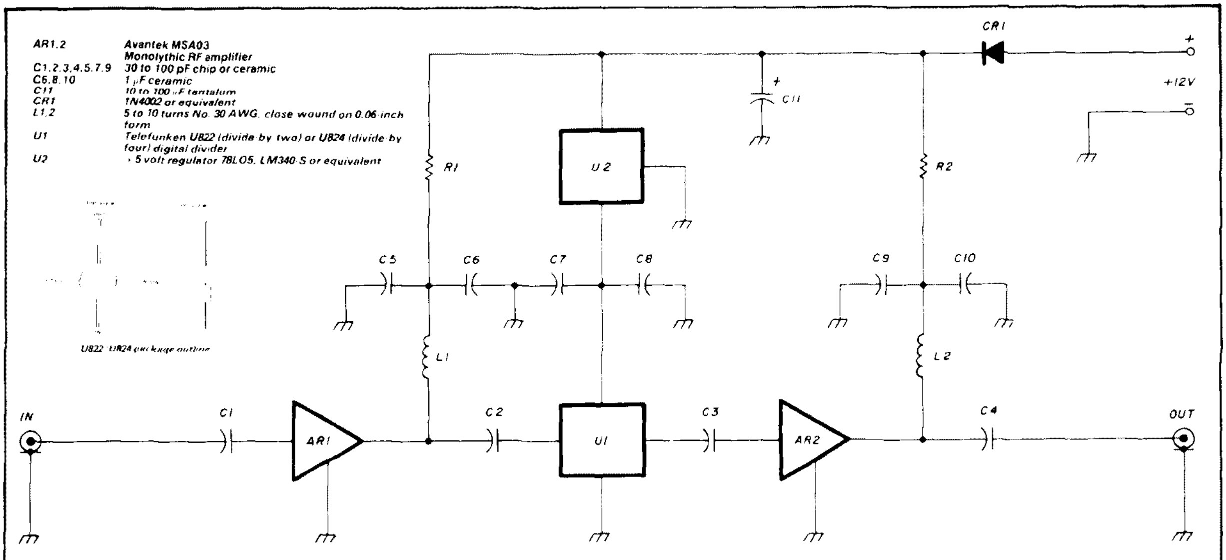


fig. 4. Prescaler schematic diagram.

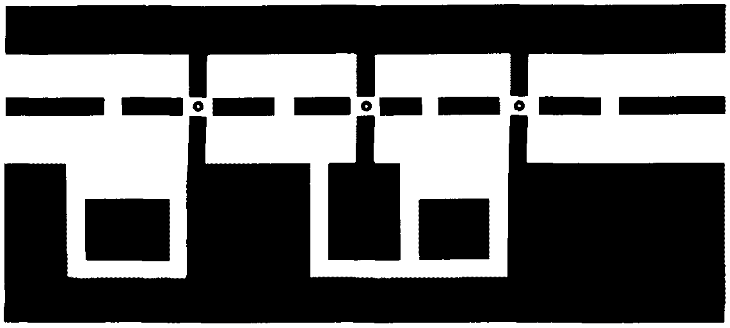


fig. 5. Full-size pc negative for the prescaler.

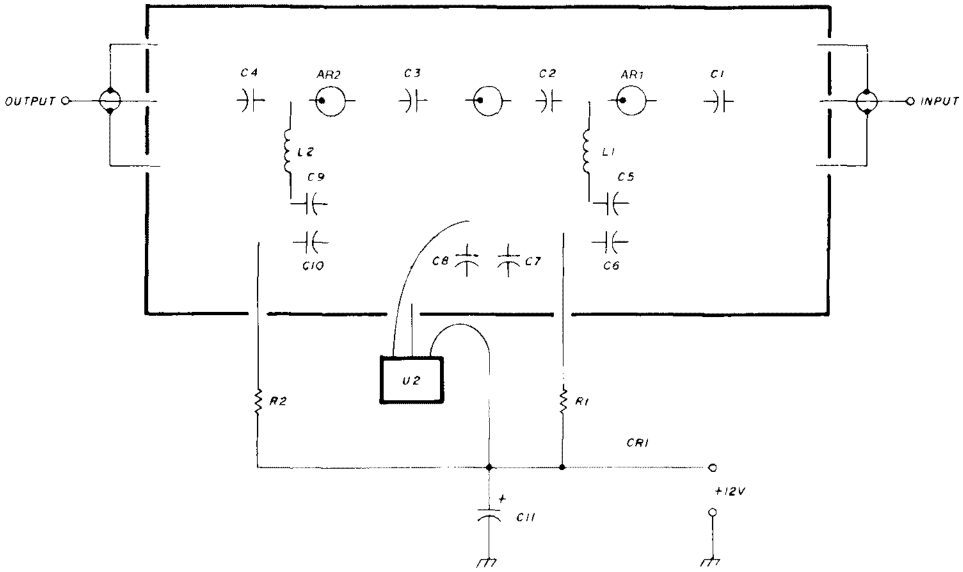


fig. 6. Component locations. Items shown off board are mounted on sidewall of enclosure.

prescaler operation

Figure 4 shows the schematic diagram of the prescaler. The rf signal enters at the left and is coupled to the MSA03 amplifier through a small capacitor. The capacitor can be a small mica type — but for more uniform results and flatter gain response, I recommend using a chip capacitor. Reference 2 describes the selection of capacitor type and value in detail. Any capacitance from about 30 to 300 pF is a fair choice here, and will work for the 1- to 2.5-GHz range. At the output of the MSA amplifier, a second capacitor of the same type is used to isolate the DC supply, which reaches the amplifier through a small, hand-wound choke. Resistor R1 biases the amplifier, and for a 12- to 15-volt supply 200 to 240 ohms is appropriate.

The U822 requires + 5 volt bias, which is just a bit too low to be used on the MSA amplifier. Rather than run two separate power supply leads to the prescaler, a small voltage regulator is used to drop the 12-volt to 15-volt input to the 5 volts needed by the divider. Because the divider draws only about 30 mA, a small voltage regulator IC such as the 78L05 can be used. No heatsink is required at this power level.

Following the divider a second rf amplifier buffers the divider's output and increases the divided output signal to a higher power level. The U822 provides about + 20

dBm output into 50 ohms. Because this level is too low to drive many frequency counters, another MSA03 amplifier brings the signal up to about −8 dBm. If the second amplifier isn't needed, it can be omitted. Install jumpers over the cuts in the microstripline to complete the circuit from C3 to the output connector. If AR2 isn't installed, then C4, C9, C10, R2, and L2 may also be removed.

At the right, the divide-by-two output leaves the output connector. The U822's output is direct-coupled, so a coupling capacitor is used to prevent unwanted biasing of the divider by external voltage sources.

construction

The prescaler is built on a circuit board that can be etched from the full-sized negative artwork shown in **fig. 5**. Alternatively, a prototype board can be made using the same artwork, and handcutting the traces with a sharp knife and peeling away the undesired pieces of copper. With either technique, leave the far side of the board as unbroken ground to form a ground plane for the microstrip circuit traces. Wrap the edges of the board with copper tape or thin brass shim stock. Solder both edges so that the top ground areas are well-connected to the bottom ground plane. The two ground leads from the MSA are run through the 0.15-inch hole in which the MSA amplifier is mounted. Then they're soldered to the ground plane on the far side of the circuit board. The output of the amplifier MMIC device is identified by a small bump on the top of the package next to the output lead.

The U822 divider is also mounted to the board in much the same way. A 0.2-inch hole is drilled in the board to clear the circular plastic package. The leads are then soldered flush to the traces, which connect them to the rest of the circuit. The U822 has four leads, as **fig. 6** shows. One lead each is used for the rf input, the divide-by-two output, ground, and +5 volt bias. The longest of the four leads is the output. The bias lead of the U822 should be well decoupled to ground. I used a chip capacitor, a small ceramic disk capacitor, and a tantalum slug capacitor. This combination, I hoped, would provide good RF decoupling at frequencies from a few Hz up to several GHz.

The biasing circuitry for the MSA and the voltage regulator are hooked up point-to-point along the edge of the circuit board and to the mounting points of the enclosure. Their locations are not critical if the rf amplifiers and the divider have been effectively decoupled on the board.

performance

Figure 7 shows the performance of the prescaler with its preamplifier in place. The improved dynamic range is markedly different from the operating window seen in **fig. 2**. With its preamplifier, the prescaler now has a much better input signal range, both above and below

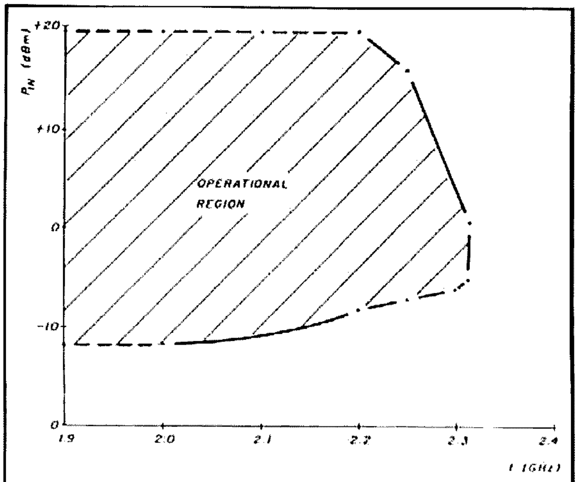


fig. 7. Performance of the U822 with MSA03. Dashed lines indicate limitations of the rf signal generator.

the levels which the divider alone could handle.

In recent years, digital integrated circuits have made it possible to build digital frequency counters for microwave frequencies. Just ten years ago, the fastest available counters operated at about 1200 MHz, but silicon bipolar dividers now on the market operate more than twice as fast. New Gallium Arsenide (GaAs) digital chips are in limited production, and although they're still too expensive for Amateur use, they promise yet another leap in performance in the near future.

references

1. Jerry Hinshaw, N6JH, "1.5 GHz Divide-by-four Prescaler," *ham radio*, December, 1978, page 84.
2. Jerry Hinshaw, N6JH, "Monolithic RF Amplifiers," *ham radio*, March, 1986, page 22.
3. B. Atkins, KA1GT, "Microwave Amplifiers," *QST*, January, 1986, page 78.
4. J. Browne, "GaAs IC Complements Budget 3 GHz Counter," *Microwaves and RF*, January, 1986, page 221.
5. JA6BI, "High Frequency Dividers," *CQ Ham Radio*, August, 1985, page 355 (in Japanese).

ham radio

short circuits

rewinding transformers

Pages 89 and 90 of W6WTU's article, "Rewinding Transformers with CAD (December, 1986) were transposed. —TNX WB4UIV

SSTV with C-64

The address of the Journal of the Environmental Satellite Users' Group was shown incorrectly in the October article, "Get on SSTV with the C-64" (page 43). The correct address is 2512 Arch Street, Tampa, Florida 33607. (TNX WD4MRJ)

ham radio

X-band beacons

A practical guide to component selection, installation, and operation

On the low bands, distant signals are almost always available to aid in adjusting antennas, checking out equipment, and investigating propagation. This isn't so on the microwave bands, where contests may provide the only microwave signals you're likely to hear. By the time the contest arrives, however, it's much too late for extensive testing of any kind.

One way of solving this problem is through use of a beacon that provides an ever-present, stable (but distant) signal. Fortunately, microwave beacons aren't particularly difficult or expensive to build.

Part 97, section 97.87 of the FCC regulations provides for Amateur beacons. All frequencies above 450 MHz — and some below 450 MHz — are available for automatically controlled beacons. Although no special authorization is required, some form of control is necessary.

I've had a X-band (10 GHz) beacon operating from a 2000-foot mountain near Ventura, California, for several years (see **fig. 1**). Coastal southern California is its intended coverage area.

The heart of the beacon is a 140-mW Gunn diode source operating on 10.256 GHz. The Gunn diode is fm-modulated with the repeating Morse message: "WA6EJO/B Ventura X band beacon." Control is provided by the W6ORE remotely controlled station (**fig. 2**),[1] which simply turns the beacon's power supply on and off. Although this article pertains to building an X-band beacon, the same techniques can be applied to any microwave band where simple rf sources are available.

An X-band beacon consists of a signal source, an antenna, an IDer, a power supply, a weatherproof housing, and a control unit.

signal sources

A Gunn diode oscillator is a typical X-band source. The Gunn diode itself* is usually packaged in a small metal box or casting. There's a terminal for dc bias and an opening for the rf output. Pre-packaged Gunn diode oscillators used in intrusion alarms and police radars often appear on the surplus market.

The dc requirement ranges from about 5 volts to 15 volts, at a current level of tens to hundreds of milliamps, depending on the particular unit. This power should be well regulated because voltage fluctuations will result in fm-ing the frequency of the output (which comes in handy for modulation).

The power output is in the tens to hundreds of milliwatts — not levels capable of inducing rf burns, *but eye damage is a possibility*. Keep microwave sources, even weak ones, away from your head!

The frequency can usually be adjusted over a wide range, often hundreds of MHz, with a mechanical tuning screw. These are free-running, not crystal-controlled, oscillators. Nevertheless, they're surprisingly stable after a few minutes warm-up. Sources from intrusion alarms and speed radars are usually tuned to 10.525 GHz, slightly above the Amateur band.

The Gunn diode oscillator used in my beacon is a surplus police radar unit purchased from Lectronic Research Laboratories for $50.** While that may not seem to be a bargain — I have picked up Gunn oscillators at swap meets for $5 — the power output is quite high. The unit is rated at 100 mW and, when measured, produced 140 mW.

Equally usable are IMPATT (IMPact ionization Avalanche Transit Time) diode sources, which take more voltage (70 to 90 volts), and Dielectric Stabilized Oscillators (DSO). Klystrons are definitely passé. Solid-state sources are generally cheaper, longer lasting, and safer (no high voltage).

When purchasing surplus microwave hardware, it's

*Actually, the Gunn diode is not a true diode. It has no PN junction, but does have a designated anode and cathode.

**Lectronic Research Laboratories, Atlantic and Ferry Avenue, Camden, New Jersey 08104.

By **Steve J. Noll, WA6EJO**, TiC Scientific, 1288 Winford Avenue, Ventura, California 93004-2504

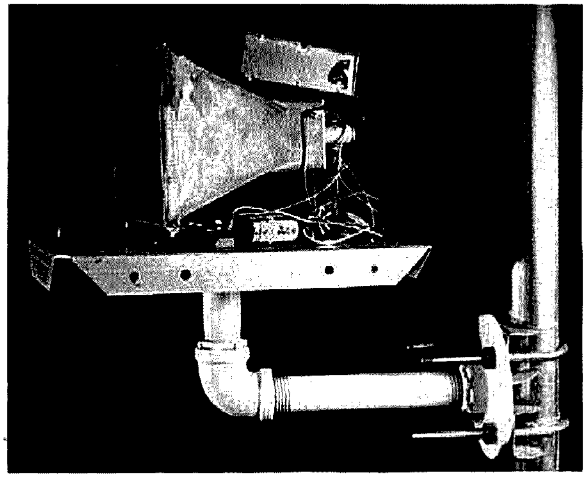


fig. 1. Beacon with cover removed.

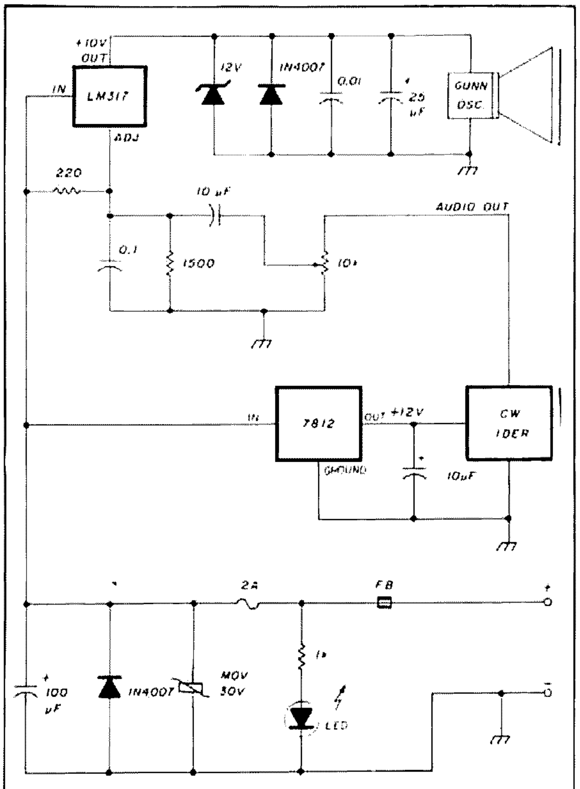


fig. 2. Beacon schematic.

important to make sure you're getting the correct frequency range. The designation "X-band" actually covers a very wide range of frequencies, from 5.2 GHz to 10.9 GHz, with several different sizes of waveguide available. Rectangular waveguide is the transmission line of choice because sources, antennas, and other hardware are usually built to mate with rectangular waveguide flanges.

The Amateur Radio Service portion of X-band is 10.0 GHz to 10.5 GHz, which includes the X_F and X_K sub-bands. The waveguide we are interested in measures 0.9 x 0.4 inches inside, and 1 x 1/2 inches outside. The designations for such guide are WR-90 (EIA) and RG-52/U (MIL). The flanges of interest are UG-39 and UG-40.

The waveguides for the frequencies just above and below the Amateur band differ only slightly in dimension; it's easy to pick the wrong one. When shopping at electronic swap meets, hamfests, or surplus stores, it's wise to carry a ruler or a waveguide flange of the correct dimensions for comparison.

Note that sources may actually have smaller rf output openings than the standard waveguide inside dimensions. In fact, the rf port may be just a round hole. Because of this, it's more important to judge surplus source frequency range by checking the spacing of the four No. 8 mounting holes at the flange corners. The spacing for UG-39 and UG-40 flange holes is 1-7/32 x 1-9/32 inches.

Let's say you've picked up a purported Gunn diode oscillator at the local swap meet or surplus emporium, but its voltage requirement isn't marked. Now what? Fortunately, it's not difficult to determine the optimum bias for a Gunn diode. An adjustable power supply, an attenuator, and a detector — or preferably, a power meter — are required.

Connect the source to the detector/power meter through the attenuator (10 or 20 dB, for protection). Run the supply voltage up, starting from 5 volts, and monitor the power output. It should peak somewhere between about 6 to 14 volts and then decline. *The peak is the operating point.*

I've applied this technique to three different X-band Gunn sources (**fig. 3**). A Solfan source started oscillating at 4 volts and had a broad peak at 8 volts with 8.5 mW out. A Racon source started oscillating at 4.5 volts and peaked at 9 volts with 30 mW out. A Greenray source started oscillating at 9 volts and peaked at 12 volts, with a 130-mW output.

A couple of important details: spurious low frequency oscillations can destroy a Gunn diode. (This can be prevented by connecting a 15- to 35-µF capacitor and a 0.01-µF capacitor across the diode.) Also, Gunn diodes can be damaged by reverse polarity. Usually the case of the Gunn oscillator is negative.

antennas

Although there are other kinds of microwave antennas, horns (**fig. 4**) are probably best for most beacon applications. They're commonly found on the surplus market, but if you can't find one, it's not difficult to make one from a short piece of brass waveguide, a brass flange, and some sheet brass (**figs. 5A, 5B**)

available from hobby shops.* Horns are also reasonably efficient and don't require tuning.

Where to get waveguide and flanges? Check surplus stores and swap meets for miscellaneous waveguide assemblies that have salvageable parts. But avoid aluminum waveguide and brazed brass waveguide unless it's already in a usable form. Soldered brass waveguide and flanges are best because they can be taken apart with a torch. Another source is Lectonic Research, which sells brass flanges (in the $3 to $6 range) and waveguide (at about $4 per foot).

A horn is a directional antenna and essentially a flared, open waveguide. Short, small horns have wide, low-gain patterns; long, large-aperture horns have more gain and less beamwidth. Ideally, a microwave beacon should be positioned so that all users are situated in one direction from it. Power is hard to come by at X-band, so it's a shame to waste it on a wide-beamwidth antenna.

What sort of gain and beamwidth is available from horns? The small horn used on the Microwave Associates Gunnplexer transceiver, for example, measures 3 inches long and has an aperture measuring about 3 inches by 3-1/2 inches; the gain is approximately 17 dB, with a beamwidth of 30 degrees. The Microlab/FXR X638A, a large X-band horn, measures 15 inches long and has a 7-5/8 by 5-5/8 inch aperture; the gain is 22 dB, with a beamwidth of about 12 degrees. As you see, as gain rises, horns get longer.

identifying

Part 97.84d3 requires that beacons be identified at intervals not to exceed 1 minute. If ID is by voice, the word "beacon" must follow the call sign. If ID is by CW, the call sign must be followed by the fraction bar DN and the letters "BCN" or "B." Although speech synthesis and speech recording chips are available, it's probably still cheaper and better to identify with CW. Commercial CW IDers are available. GLB and Autocode** are two manufacturers of IDers in the $50 price range. An IDer can be built, of course, and few parts are required. The WB2BWJ IDer is quite popular.[2,3,4]

Although SSB is on the way, most 10-GHz stations still use fm because the popular Microwave Associates Gunnplexer was designed to work on fm. Therefore, fm modulation of the beacon is in order, and it's fortunately quite easy to accomplish. As noted, power supply fluctuations will fm the rf output of a Gunn diode. So all that needs to be done is to inject a little modulated CW audio into the diode via a coupling capacitor.

*See the RSGB *VHF-UHF Manual* for horn construction details.

**GLB Electronics, 151 Commerce Parkway, Buffalo, New York 14224; Autocode, P.O. Box 7773, Westlake Village, California 91359.

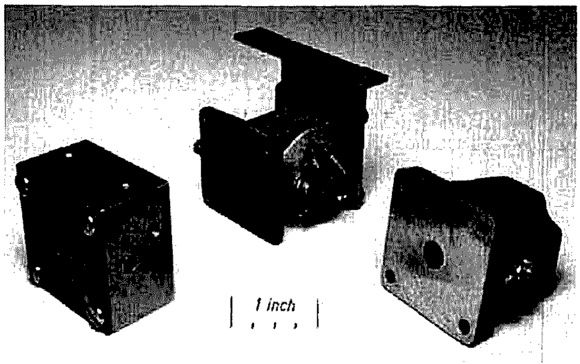


fig. 3. Surplus X-band Gunn Oscillators.

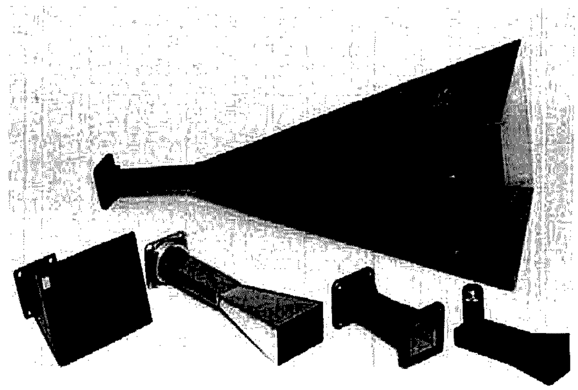


fig. 4. Examples of X-band horn antennas.

How much audio must be injected? That depends on the fm bandwidth of the receivers that will be monitoring the beacon. Probably the easiest way to determine the best amount is to adjust the IDer level while listening to the beacon output with a receiver typical of the type that will be monitoring the beacon.

In the case of my beacon, 100 mV peak-to-peak was required for a good signal as heard on a Microwave Associates Gunnplexer with a 3-dB-i-f bandwidth of 25 kHz. This voltage was measured at the Gunn diode. The IDer audio is actually coupled into the ADJ pin of the LM317 voltage regulator powering the Gunn diode.

power supply

Nothing's critical here. My beacon, including regulators, 140-mW rf source, IDer, and pilot light, draws a total of 400 mA from an unregulated 20-volt power supply. The unregulated supply is located in a cabinet, some 70 feet below the tower-mounted beacon. The supply consists of a 6-amp transformer, full-wave bridge rectifier, capacitive filtering, fuse protection of the line side, circuit breaker protection of the load side, and a solid-state relay for control. The raw dc is piped

up to the beacon via coax cable. The voltage regulators, a 7812 for the IDer and an LM317 for the Gunn diode, are located in the beacon housing.

Why not regulate the dc at the base of the tower? There are several reasons: voltage drop is one. The 20-volt supply allows for plenty of voltage drop in the trip up the tower. This also allows for more beacons to be added later by tee-ing power off the coax. Regulation right at the load also avoids hum and rf pickup that could occur through 70 feet of line.

lightning protection

Nothing but luck will save equipment actually struck by lightning. Serious damage from near strikes, however, can be avoided. A near strike took its toll on my beacon once and the result was blown fuses, a tripped circuit breaker, a blackened neon pilot light, a destroyed voltage regulator, and burned paint on the power supply. But there was no damage to the valuable parts, the IDer, or the Gunn diode! This fortunate outcome wasn't entirely attributable to chance. The beacon and its power supply were judiciously designed using fuses, Metal Oxide Varistors (MOVs), polarity protection diodes, ferrite beads, and surge-absorbing capacitors. The three terminal voltage regulators have an innate capacity for load protection. And using coax instead of a pair of open wires for supplying power helps reduce induced voltage. Design as much protection in as possible; it just might pay off!

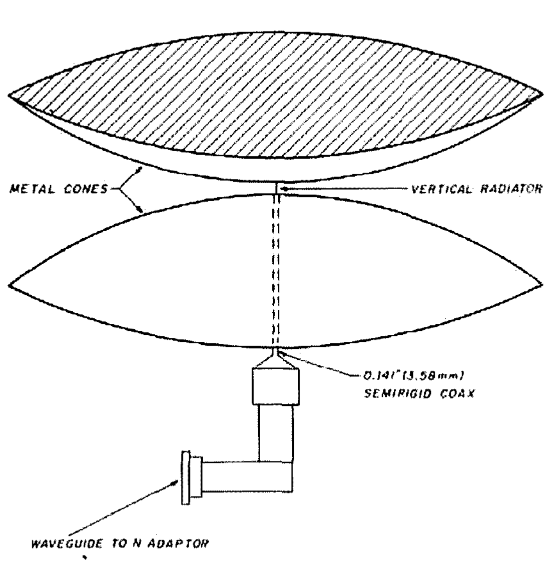


fig. 5A. Biconical horn antenna, vertically polarized.

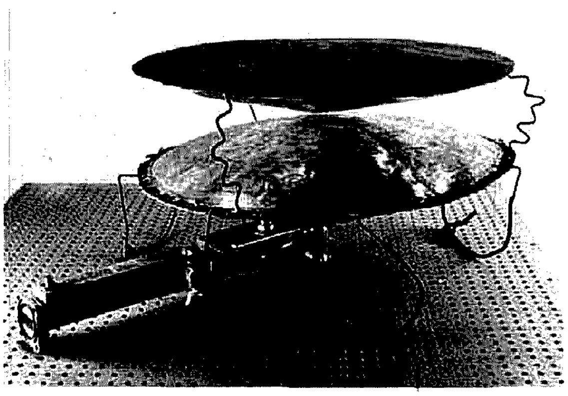


fig. 5B. Prototype X-band biconical horn.

beacon enclosure

Presumably the horn antenna, rf source, and IDer will be mounted on a tower or pole of some sort. All are small enough to fit inside an enclosure less than a half cubic foot in volume. The horn needs to "look" into the atmosphere through an rf-transparent window, so at least one wall of the enclosure has to be made from a suitable dielectric.

Finding an appropriate plastic box is no small feat. Sunlight can be quite destructive; it will disintegrate some plastics in a very short period of time. (For example, polyethylene trash bags left in sunlight will deteriorate in a few weeks. White nylon cable ties crumble in a few months.) Plastics often contain ultraviolet stabilizers to improve their sunlight resistance, but you can't tell by looking if a given piece of material contains UV stabilizers or microwave-absorbing additives.

Some have suggested testing the rf absorption of a material by placing it in a microwave oven, saying that if the material gets hot, it shouldn't be used. This sounds reasonable, but I really don't know how valid it is. Another test involves placing a piece of the proposed rf window material in front of a Gunnplexer and noting if much frequency "pulling" occurs, or if there's a change in mixer current caused by reflection. In the absence of any actual rf attenuation measurement capabilities, this method seems more reliable.

Some possible enclosures include plastic food storage containers, small plastic trash cans, computer diskette storage tubs, or wood or metal boxes with glass or Fiberglas™ windows. *Styrofoam™-type materials* might not be advisable because birds would be able to peck through them readily.

I was lucky to find a plastic box perfect for this application (**fig. 6**). It once housed a roof-mount Multipoint Distribution Service (MDS) 2-GHz receiver and antenna, so its microwave transparency and weather resistance were already proven. I further protected the box from sunlight by covering all sides except the one that the horn shot through with adhesive aluminum tape.

I covered the Gunn oscillator with building insulation to slow temperature changes, and thus, frequency

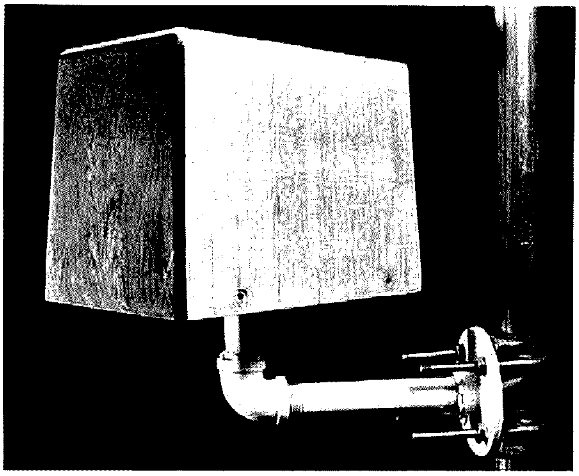


fig. 6. Beacon with cover in place.

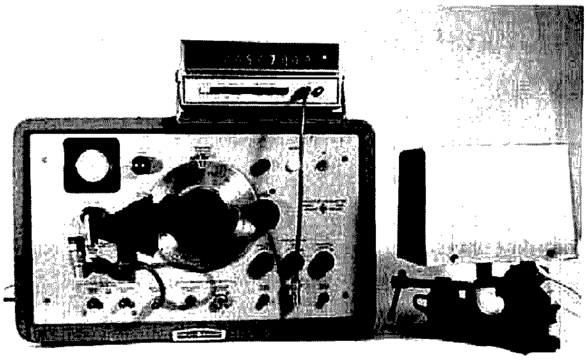


fig. 7. Measuring beacon frequency with an HP-540B transfer oscillator.

drifting. You can cover the horn opening with plastic food wrap (such as Saran Wrap™) to slow air migration-induced temperature changes. For perfectionists who want to provide active temperature control, several circuits are described in the *Gunnplexer Cookbook*.[5]

control circuitry

Part 97.87b says, "A station in beacon operation, either locally controlled or remotely controlled, may also be operated by automatic control when devices have been installed and procedures have been implemented to ensure compliance with the rules when the duty control operator is not present at a control point of the station."

One can't just park a beacon on a hilltop and forget about it; control is required. This would presumably mean simply being able to turn it on and off. Ideally, a beacon would be located at an existing repeater or remotely controlled station (Remote Base) site and share the control link.

My beacon, or more specifically, its power supply, is operated by the control link of a remotely controlled station. If a control receiver must be built for your beacon, remember that Part 97.86d allocates all frequencies above 220.5 MHz, except 431-433 MHz and 435-438 MHz, for controlling ("auxiliary operation").

choosing a frequency

The Amateur X-band covers 10.0 GHz to 10.5 GHz. Considering the possibility of drift, it would be wise to stay clear of the band edges. The rigs most likely to use the beacon, the Microwave Associates Gunnplexers, are usually operated around the middle of the band anyway.

How do you find the middle – or for that matter, *any* portion of the band? If you don't have access to a microwave frequency counter or wavemeter, one way is to use a Gunnplexer for a receiver and tune the beacon until it's heard. But how do we know where the Gunnplexer really is? You could build up a calibrator from a crystal oscillator and multiplier chain, hit a snap diode (an SRD) with a few hundred MHz of rf and generate a wee bit of X-band. Or, you could just hit a diode with a hundred mW or so of 146.52 MHz from a common 2-meter handheld.[6] The 70th harmonic will be 10.2564 GHz, close enough to the middle of the band.

Another affordable method of microwave frequency measurement involves using a surplus Hewlett-Packard 540B transfer oscillator (**fig. 7**). This instrument consists of a tunable 100- to 220-MHz oscillator, a diode mixer, and a small oscilloscope. The oscillator output and the signal to be measured are both applied to the diode mixer, which serves as a combination harmonic generator and mixer. The oscillator is tuned until a zero beat is observed on the oscilloscope. If we know, for example, that the source is somewhere between 10.1 GHz and 10.4 GHz, and tuning the 540B oscillator yields a zero beat at 205 MHz, the source is at 10,250.0 GHz (205 MHz x 50th harmonic). There are procedures given in the 540B manual for figuring the source frequency if the possible range is wider (approximate source frequency unknown). A frequency meter output is provided on the 540B for connection of a counter to obtain higher resolution than is provided by the oscillator dial. The source signal can be picked up by connecting a small horn antenna to the 540B mixer input with a waveguide to a type N adapter. The 540B will measure frequencies from 10 MHz to at least 12.4 GHz.

Remember, the packaging, and anything else near the front of the horn will "pull" the frequency somewhat. So whatever method is used for determining the beacon frequency, be sure that the final measurements are made with the beacon in its finished, packaged form.

expected range

How far away can you expect to hear an X-band beacon? Assuming a line-of-sight path, a 15-mW beacon, a Gunnplexer receiver with a very narrow (15 kHz) i-f, and small 17-dB horns on both beacon and Gunnplexer, you can expect a range of about 100 miles. With an 80-mW beacon and the same set-up, you can expect a range of about 200 miles. For a wide (200 kHz) i-f, 15-mW beacon, and two 17-dB horns, expect a range of about 30 miles, and about 60 miles for an 80-mW beacon.

If you use a 2-foot dish at the receiver and a 17-dB horn at the beacon, figure about 150 miles for a 15-mW beacon and wide i-f, 300 miles for an 80-mW beacon and wide i-f, 600 miles for a 15-mW beacon and narrow i-f, and a whopping 1200 miles with an 80-mW beacon and narrow i-f.

improvements

The best improvement you could make to the simple beacon presented here would be to increase the frequency stability. This would make the beacon not only an excellent tool for checking propagation, but also a frequency standard.

The easiest way to achieve better stability is through temperature control; proportional temperature control methods are discussed in the *Gunnplexer Cookbook*. [5] Better yet is to phase lock the Gunn oscillator to a crystal-controlled signal. Techniques for doing this with Gunnplexers, also described in the *Cookbook*, could probably be adapted to simple Gunn diode sources.

One might consider impressing telemetry on the beacon's signal. For example, it would be interesting to monitor the air temperature at the beacon site (as well as at the receive site) and see if there's any correlation between air temperature and signal strength. Ducting or inversions might be detected in this way. One possible method would be to connect an LM34 Fahrenheit temperature sensor IC* to a 566 voltage-controlled oscillator IC. The resulting temperature-dependent tone would be used to modulate the Gunn source between IDs. A frequency counter on the X-band receiver would measure the tone frequency and yield the corresponding temperature.

Another telemetry candidate is relative humidity. Humidity sensors haven't been commonly available, but now Mepco/Electra (Philips) makes one that changes capacitance with humidity.**

Still another option would be the ability to pipe the audio from the control link through the beacon. This would allow one-way X-band QSOs.

For better coverage, one might be tempted to install several Gunn sources on the same tower, each pointing in a different direction. Unfortunately, this is prohibited by 97.87a: "A station in beacon operation shall not concurrently operate on more than one frequency in the same amateur frequency band, from the same location."

Though it's not practical to get several free-running Gunn oscillators on exactly the same frequency, there may be other ways around this restriction. For example, each Gunn source could be served by a different IDer bearing the call of an Amateur responsible for that particular source. Or, each source could be switched on, IDed, and then switched off in succession so that none were operating concurrently.

operation

Although the 140-mW beacon is only 11 miles from my QTH, I've never been able to copy it there because of a small peak located in the middle of the path. It's estimated that the peak blocks the path by about 50 feet; even a Gunnplexer with a 2-1/2-foot dish won't pick up any knife-edging, although 1296-MHz signals over the same path are very strong. Other knife edge-dependent shots have been tried without success.

When the path is truly line-of-sight, the beacon signal is, of course, quite strong. It has even been picked up around town, while mobile! In this case, the receive antenna was a vertically polarized, omnidirectional gain biconical horn fashioned from two pizza pans; the flat pans were beaten into cones and mounted with their apexes almost touching. A tiny driven element between the apexes was connected to the Gunnplexer with a waveguide-to-coax adapter. The whole works — essentially a horn spun about the vertical axis — was then mounted on the top of a truck camper shell. (The biconical horn might make a good beacon antenna if an omnidirectional pattern is necessary.)

conclusion

A microwave beacon is a worthwhile project that can benefit many Amateurs. It isn't particularly difficult to build; perhaps the most difficult part is simply finding a site at which it can be installed. Might a beacon be just the catalyst you need to spark microwave activity in your area?

references

1. Steve Noll, WA6EJO, "Remotely Controlled Stations: A Look at A Successful Remote Base," *ham radio*, September, 1986, page 48.
2. Michael J. DiJulio, WB2BWJ, "Versatile CW Identifier," *ham radio*, October, 1980, pages 22-25.
3. Michael J. DiJulio, WB2BWJ, "An Improved Memory For the Versatile CW Identifier," *ham radio*, February, 1982, pages 24-26.
4. Michael J. DiJulio, WB2BWJ, "Short circuits," *ham radio*, February, 1982, page 70.
5. Bob Richardson, W4UCH, "Gunnplexer Cookbook," *Ham Radio Publishing Group*, Greenville, New Hampshire 03048 (Chapter 5)(out of print).
6. Steve Noll, WA6EJO, "X-band Calibrator", *ham radio*, April, 1981, page 44.

ham radio

*Digi Key Corporation, P.O. Box 677, Thief River Falls, Minnesota 56701.
**Goldsmith Scientific Corporation, 720 East Industrial Park Drive, Manchester, New Hampshire 03103.

top-down filter design

Structured programming guides ladder filter design using real components

The design and construction of filters is a topic of increasing importance to Radio Amateurs. Mathematical advances in filter theory — from the simple m-derived filters so common two decades ago to those of today — have been paralleled by an increasing sophistication in the design of Amateur equipment requiring such filters. This trend can be seen by comparing the mere two pages of filter design information in the 1957 edition of the *ARRL Radio Amateur's Handbook* to the multiple pages, complete with design tables and an extensive bibliography, in the 1986 *Handbook*.[1]

However, it's one thing to design such a filter and an entirely different thing to construct one that works, especially at radio frequencies. Filters are designed assuming purely resistive terminations with perfect inductors and capacitors. Real filters are built with lossy reactive components, often with reactive terminations, and always with additional "components" in the form of lead inductances and stray capacitances. Sometimes, also, a series "trap" is added in parallel with the output of a filter to remove a particularly troublesome signal. These factors, then, may cause the frequency response of a real filter to be considerably different from the desired design response.

This article describes a computer program which will calculate the frequency response of a filter made from *real* components. Many Amateurs now have access to personal computers and can therefore "measure" the response of a real filter without building it and without the laboratory equipment that would be necessary to actually measure the response. The program is particularly useful for evaluating the response of a filter which is not terminated in its design load, but instead in some other impedance — for example, a tuned circuit.

The program is designed to analyze ladder filters (fig. 1). Most common filters are of this form.

software design requires planning

It's a sad fact that most engineers and scientists are self-taught programmers. As such, they may not realize that a program must be "engineered" just as thoroughly as any hardware project. All too often, they may just start in writing code without having thought through the overall structure of the program. This is the software equivalent of starting the design of a receiver by calculating the values of resistors in an i-f amplifier.

Just as hardware design is approached from the overall to the specific — starting with block diagrams and desired stage characteristics — so must a program be designed from the outside inward. This is called "structured programming." Good programming techniques are important if the resulting programs are to be bug-free and robust. There are, alas, not many examples of this kind of software design in the Amateur literature, and many programs appearing in the Amateur literature are very poorly designed. The impetus to write this article came as much from a desire to help stamp out poor programming practices as a wish to share a very useful program.

This article, then, is a construction article. . . but it will be a program, not a piece of hardware, that is constructed.

The essence of structured programming is to describe the problem as clearly as possible. In this case, we want to analyze the attenuation vs. frequency response of a filter made with real components. The principal difficulty is that there is no simple way of characterizing a real component which is valid over a wide frequency range. Obviously, we can represent any component as a complicated, frequency-varying impedance. Such a representation is difficult to handle, and also presents the problem of somehow measuring real components in order to find out how they

By J. A. Koehler, VE5FP, 2 Sullivan Street, Saskatoon, Saskatchewan S7H-3G8

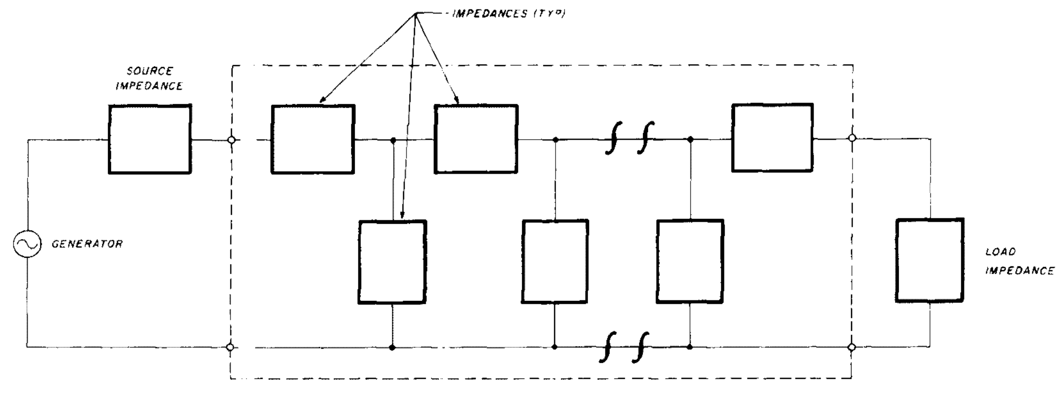


fig. 1. Block diagram of typical ladder filter.

fig. 2. Equivalent circuit for a real capacitor.

Table I. The quantities needed to specify a real component.

Component	Quantities needed
Capacitor	Capacitance, lead inductance
Resistor	Resistance, lead inductance
Inductor	Inductance, Q, stray capacitance

vary with frequency. This approach is, in practice, unusable. The question is, how detailed should our model of a component be in order to give an adequate representation of its characteristics?

Consider a real capacitor, for example. The equivalent circuit of a real capacitor, as shown in **fig. 2**, can be represented by a series circuit consisting of a capacitor, an inductor, and a resistor. The problem arises because no single value for any of these components is completely valid for *all* frequencies.

Fortunately, for most real capacitors used in rf circuits (such as silver mica, polystyrene or small value NPO ceramic capacitors), the resistance value is close to zero and may be neglected. The inductance is due partly to the capacitor leads and partly to the internal construction of the capacitor, but can be fairly represented by just the lead inductance. We can therefore consider a real capacitor to consist of a capacitance in series with a lead inductance and have a model which is fairly good over a wide frequency range.

Similarly, real resistors have inductive and capacitive elements. However, the stray capacitance across a resistor may usually be neglected and a real resistor can be represented as a perfect resistance in series with a lead inductance.

The most troublesome component is a real inductor. Real inductors have easily measurable losses as well as a stray capacitance which may be significant. The loss term is normally very frequency-dependent; one way of describing it is to use the Q value of the inductor according to:

$$R = 2\pi fLQ$$

where R is the equivalent resistance *in parallel* with the inductance. Unfortunately, this is only a first-order approximation. However, for filter responses over just a few decades in frequency, it's reasonably valid and provides a basis for computation. A real inductor, then, will be specified by an inductance, a Q value (valid for the frequency range of the desired filter response) and a stray capacitance. Fortunately, all these values may be fairly easily determined for a real inductor — the inductance and Q value by means of a bridge and the stray capacitance by measuring the self-resonant frequency of the inductor with, for example, a grid dip meter.

To summarize, real components of capacitors, resistors, and inductors may be specified by the quantities shown in **table 1**.

The basic circuit which is analyzed is that shown in **fig. 1**, but where every box is represented by a series or parallel combination of components with each component being described by values as listed in **table 1**. The whole filter consists of a regular structure of these boxes, alternately in series and in shunt between the source and the load.

For any frequency, the basic method of calculating the filter attenuation vs. frequency response (the ratio of load to source voltage) is what Hayward has called the "tackhammer" approach.[2] Each element has

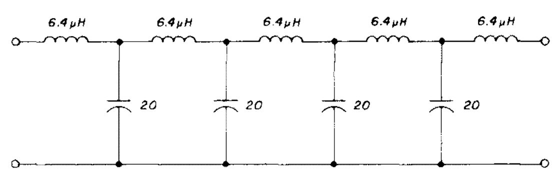


fig. 3. Circuit diagram of filter built and analyzed.

a total impedance which can be calculated for that frequency. Then, the total impedance seen by the source can be calculated by starting at the load end and working towards the source. Assuming a source voltage of 1, the current from the source can be calculated and, working back towards the load, the voltage at each node of the network and the current into the succeeding leg can be calculated. The voltage at the last node will be the voltage across the load and this value, divided by 1 volt, will be the filter response at that frequency.

This is obviously a very tedious technique because it must be done for a number of frequencies if the overall filter response is to be evaluated. However, it's admirably suited to computer calculations.

Now for the construction portion of this article: the calculations needed for the filter response are sufficiently long that using an interpreted language such as BASIC would result in unacceptably long execution times. (BASIC also doesn't lend itself to structured programming techniques.) Instead, I used a compiled version of PASCAL, which is particularly well suited to this type of program because the programmer may define new variable types. In this program, I used this feature to define complex numbers and operations used in the calculations and in the definition of component "types" used to describe the real components.

Structured programming starts at the most general level and define the overall program flow, leaving the details for last. This is directly analogous to the best way of designing hardware, which is to start at the general and work down to the specific. If you were designing a receiver, for example, you would first determine all the features desired and then draw a block diagram showing all the major functional blocks needed to produce them. The software equivalent to the hardware block diagram would be a general outline of the program as a whole. Flow charts are often used for this, but many people, including myself, prefer to use "pseudo code." This is a description of the program in cryptic English sentences, in which each sentence describes a portion of the program that does a single, definable operation. For the filter analysis program, the general steps are, first, housekeeping (setting up the program variables, initializing the arrays to be used, and opening any files necessary) and second, repetitively describing the desired filter, calculating the response, and displaying the results until you're ready to quit.

The pseudo code description of the program I first wrote was the following:

```
INITIALIZE
REPEAT
GET ALL THE PARAMETERS
DO THE CALCULATION
DISPLAY THE RESULTS
UNTIL DONE
```

Having the equivalent of a block diagram of the program, the next steps are to break each block (in this case, each sentence of pseudo code) successively into smaller and smaller pieces of pseudo code until each sentence is just a statement in the language being used. At this point, the program is complete.

Somewhere early on in this process, it's necessary to define the form of the data upon which the program will work. In this case, the data obviously consists of a description of the filter and the frequency limits of the calculations. So, part of the process of programming requires thinking carefully about how the data will be kept. Looking at **fig. 1** again, we see that there is a regular form to the shape of the filter. Starting at the source end, there are L-shaped sections consisting of a series section along the "top" and with a "leg" in shunt. The filter consists of a number of such pieces. The symmetry is broken only by the necessity of adding a source "element" in front of the filter and by having the last "leg" of the filter be the load element.

I chose, therefore, to describe the filter as an array of "arms" where each arm consisted of a "top" and "leg" pair of "elements." Each element could consist of a series or parallel combination of up to three "components." Each component would be either a resistor, inductor or capacitor and would be described by the values given in **table 1** for that particular kind of component.

Finally, having essentially written out the program in terms of operations on complex numbers, it was necessary only to write PASCAL code to describe how the operations were done. Normal good programming practices were followed throughout.

The object is to make the source code as readable as possible. The most common failing of beginning programmers is the omission of sufficient explanation in the source code to allow others to understand how the program works. Bear in mind that you're not really preparing these comments for others but rather, for yourself — next month or next year.

The program was written to handle ladder filters with up to nine "legs." Because frequency response is usually plotted on a logarithmic scale, the program

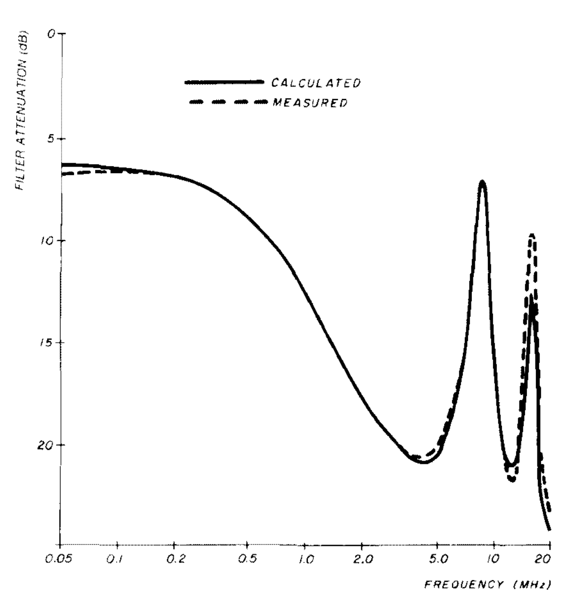


fig. 4. Comparison of measured and calculated filter response.

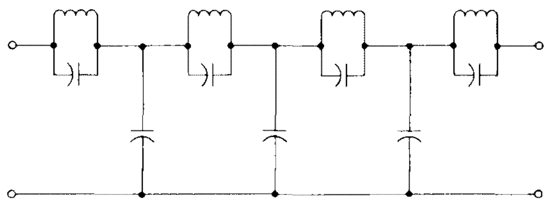


fig. 5. Circuit diagram of commercial low-pass filter.

was designed to calculate the filter response at 50 frequencies, evenly separated logarithmically, between any desired lower and upper frequency limits. Both the number of filter legs and the number of points in the frequency response can be altered in the source code and the program may be recompiled with those values instead of the ones used.

As a test for the program, a four-leg filter was constructed and its frequency response was measured on the workbench. The circuit diagram of the filter is shown in **fig. 3**. This "filter" is not a valid design, but was constructed from components on hand to see how closely the calculated filter response was to the measured one. The measured data were compared to the response calculated by the program.

Each inductor was an Ohmite Z-50 rf choke. At 7.9 MHz, the measured inductance was 6.4 μH with a *Q* of 100. These values were measured with a Boonton *Q* Meter. The parallel self-resonant frequency, measured with a grid dip meter, was 84 MHz. This corresponds to a parallel stray capacitance of 0.56 pF. The capacitors were all 20-pF, 5 percent silver-mica capacitors, each with lead lengths of about 1/4 inch in total. Using the rule of thumb that No. 20 straight wire has an inductance of 20 nH per inch, the lead inductance was estimated to be 5 nH for each capacitor.

The filter termination was a coaxial 50-ohm load and the voltage across it was measured with an HP 411A rf millivoltmeter. The program was run with lower and upper frequency limits of 0.05 and 20 MHz, respectively, and the filter response was measured at the same frequencies used in the program. For frequencies below 1 MHz, the signal generator used was a AN/URM 25D with its output passed through a 20-dB 50-ohm pad to make the output impedance 50 ohms resistive. Above 1 MHz, a Wavetek Model 3000 signal generator was used. The source and load elements were single 50-ohm resistors with zero lead inductance. As is evident in **fig. 4**, there is excellent agreement between the measured and calculated frequency responses. The disagreement between measured and calculated responses is greatest at frequencies where the filter attenuation is high and is probably attributable to measurement errors.

It's worth noting that the filter responses given by this program are all about 6 dB below what might be expected from a cursory glance at the setup. That is because, normally, filter response is given as the ratio of output to input voltage to the filter, whereas in this program the response is given as the ratio of filter output voltage to the internal "generator" source voltage. I did this because I wanted to be able to specify a source impedance which was not just purely resistive. For purely resistive sources and load *which are equal*, just add 6 dB to the program's values to get the numbers that are usually used.

As compiled, the program will handle ladder filters with up to nine legs. Although this may seem excessive, it will allow the calculation of the frequency response for many networks that may have far fewer legs. Consider the filter circuit shown in **fig. 5**. In some commercially-built versions of networks like this that I've seen, the parallel resonant circuit consisted of a small inductor and capacitor in the middle of a rather large shielded compartment with rather long leads going to the feedthrough capacitors which were in the partitions between compartments. In reality, these long leads have an inductive reactance which may be appreciable at higher frequencies. The actual circuit would be that shown in **fig. 6**.

This filter may be made into a ladder filter of the type used by the program by assuming that there are very large resistances to ground between the parallel sections and the series resistances, as shown in **fig. 7**. If values of, say, 100 megohms are assigned to these resistors, the calculated response of the filter won't be affected by them and will closely approximate the

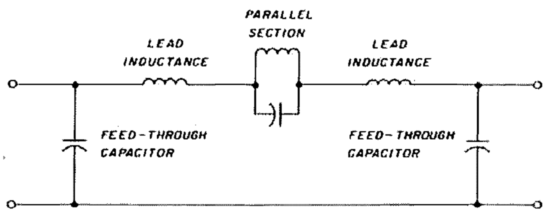


fig. 6. Equivalent circuit of one section of filter.

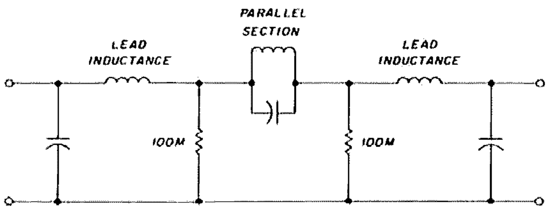


fig. 7. Filter section redrawn to be suitable for program analysis.

actual frequency response of the filter, as constructed.

A program like this allows you to predict, accurately, what the response for a real filter will likely be. I recently built a high-power (600-Watt) 6-meter amplifier. Using a spectrum analyzer, I noticed that there was a significant fourth harmonic output at 200 MHz. The problem turned out to be caused by excessive harmonic generation in the 25-Watt driver — a run-of-the-mill semiconductor, broadband amplifier. The simplest remedy seemed to be to put a low-pass filter between the driver and the final amplifier. I chose a pre-calculated standard-value capacitor (svc) design with a 3-dB corner frequency of 75.16 MHz.[2] This filter is a 7-element Chebyshev design; the schematic diagram is shown in **fig. 8**.

The program was first run for this filter with the assumption that the source and load were 50 ohm resistive, that inductors would have a Q of 100 throughout the desired range, and that the capacitors would have a lead inductance of 5 nH. The calculated filter response, very similar to the theoretical response for perfect components, is shown in **fig. 9** as a solid line. However, the load provided to the filter by the amplifier isn't purely resistive because there's a tuned circuit in the transformer-coupled grid portion of the amplifier circuit. Indeed, the input to the amplifier is more like a 50-ohm resistance in parallel with a parallel tuned circuit. Assuming that this tuned circuit would be something like a 0.1 μH inductor in parallel with 100 pF, the calculated filter response with this load is shown as the dashed line in **fig. 9** and deviates considerably from the theoretical response of the filter. Just out of curiosity, I also calculated the re-

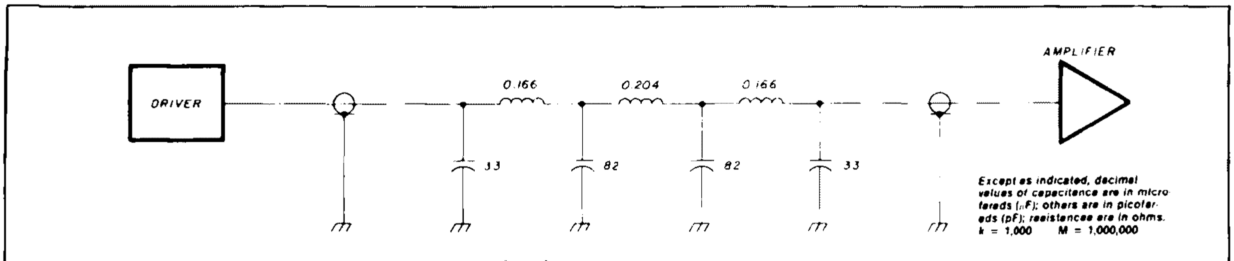


fig. 8. Low-pass filter.

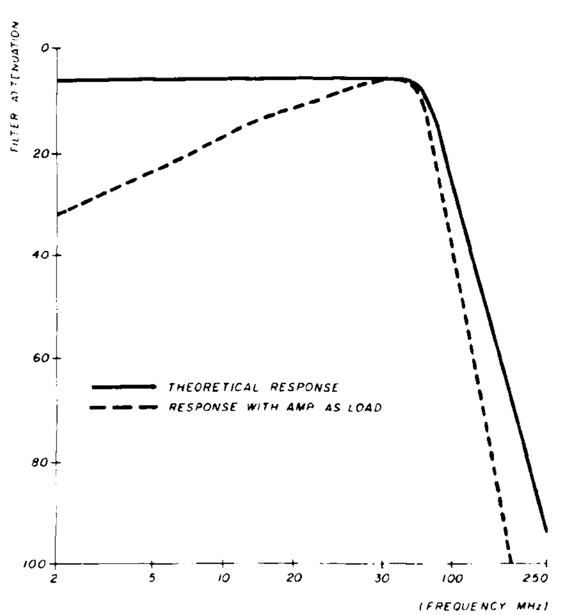


fig. 9. Response of filter no. 19 with standard load and with amplifier as a load.

sponse of the filter into the same load (the amplifier), but with a filter in which the last 33 pF capacitor was replaced with a series trap at 200 MHz (a 0.1 μH inductor in series with 6 pF). The response at 200 MHz, however, wasn't significantly affected by this "modification" to the filter, probably because the response was already down some 100 dB. Note that because of stray coupling and leakage, the practical ultimate stop-band attenuation will be less than 100 dB.

The point of all this is that the response of a filter in a real application may differ considerably from the theoretical response. This program allows one to "measure" a real filter response in a real situation.

It's also useful in examining various "what if" scenarios, in that it allows you to see what effect component tolerances have on filter response. You can observe the effects of "cut and try" solutions where you might, for example, replace a series section with a trap to remove a particularly troublesome unwanted signal. You can see what effect various load impedances have on the frequency response.

getting the program

Photocopies of the program listing (Turbo PASCAL), which is too long to reproduce here, are available from the author for an SASE and one IRC or a 68-cent Canadian stamp. Diskettes including the program source code and executable files are available directly from the author for $15 (U.S.) or $20 (Canadian), on either CP/M 8-inch SSSD diskettes, Apple II CP/M diskettes, or in an IBM PC version on IBM PC-DOS diskettes. (Both an 8087 version and a non-8087 version of the executable program are included on the IBM PC diskette. The 8087 version runs considerably faster than the non-8087 version.)

The source code was originally written in a version of PASCAL called PASCAL MT+, marketed by Digital Research; source code for this version of PASCAL is included on the diskettes. The source code alone, modified to be compatible with DEC PASCAL on a VAX, is also available as VAX files on 8-inch RX01 diskette format for the same price.

The compiled and linked version of the program on the diskettes handles filters with up to nine legs and gives 50 points in the frequency response. Both these numbers may be changed and the program recompiled if necessary. The attenuation vs. frequency response is given in dB and the phase angles are in degrees.

references

1. Filter No. 19, Table 11, page 2-42, *1986 ARRL Handbook*, American Radio Relay League, Newington, Connecticut, 1985.
2. W. H. Hayward, W6ZOI, *Introduction to Radio Frequency Design*, Prentice-Hall, 1982.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

"white noise": technology bites back

When I received my ham license in 1934 I quickly got on the air with a three-tube receiver and a one-tube transmitter. The only problem was finding the band. It took me a week to make reasonably sure I was in the 20-meter band. After much confusion, I finally had two pencil marks on the dials of my receiver and transmitter. If my signal seemed to be near the marks, there was a good chance I was inside the band.

Today my transceiver reads out to 10 Hz in its flashing digits. Quite a change from the dear, dead days of 1934! But there's a price to pay for progress, and this price is becoming apparent — especially to Amateurs living in metropolitan areas where there are many stations per square mile. The price is white noise interference (phase noise).

What is white noise interference? I can tell you this: if you have it, you know it!

Just as white light is made up of light of many different wavelengths, "white noise" is made up of an infinite number of frequencies. Theoretically, white noise goes "from dc to daylight" with infinite amplitude. If you listen to it on a receiver, it covers an extremely wide band and sounds like a sizzling, frying background noise.* When it's relatively weak, it sounds like a steady hiss. For the record, the *1986 ARRL Handbook* defines "phase noise" (which is a form of white noise) as "residual random variation of the phase difference between the synthesizer output and a perfect sine wave of the same frequency."

*On the lower HF bands it can be easily masked by atmospheric noise when an antenna is connected to a receiver. — Ed.

A representation of white noise is shown in **fig. 1**. In this hypothetical situation, the operating frequency of a signal is measured along the x-axis (frequency) and signal amplitude is measured along the y-axis. This drawing is of the white noise of a representative transmitter-exciter having a PLL (phase-lock-loop) frequency control system.[1] The desired output signal is the tall "spike" at the center frequency. Below the signal, and on both sides of it, are sidebands (the noise "pedestal"), which gradually decrease in amplitude with distance from the desired signal. At some remote frequency, the noise sidebands disappear into the noise floor of the receiving system.

Spectral impurity, or phase noise, can be measured with reference to the noise floor or to the amplitude of the desired signal. It is commonly specified in terms of strength in a given bandwidth, measured a certain frequency from the main carrier. While spectral impurity is not specified for Amateur equipment, it is often given for commercial or miltary gear; the AN/PRC-117 transmitter, for example, has a noise limit of −162 dB/Hz, referenced to the carrier (dBc) at frequencies greater than ±10 percent from the carrier.

A popular microwave signal generator has a specification or phase noise of greater than −185 dBc (referenced to carrier) at 10-kHz spacing from the carrier.

These specifications imply a certain difficulty in measurement, since the measuring equipment is working with a signal ratio of much greater than 100 dB! Measurements of this type aren't done in the ham shack, or even in a reasonably well-equipped lab! They're not something a ham can easily check out and quantify on a late Saturday morning when the band is dead.

Nevertheless, white noise interference is becoming quite bothersome in areas of intense ham activity, particularly during contests. Unfortunately white noise generated in a PLL-type exciter is passed through a linear amplifier and boosted along with the desired signal.

on-the-air effects

An easily-recognized symptom of white noise is a rushing sound adjacent to a strong carrier. Let me give you an example. Tests were run between my station and a local Amateur, about 3 miles away. We aimed our beams at each other one morning when the band was "flat." My friend's signal was 30 dB over S9 on my receiver. As he sent slow dashes, I tuned back and forth on each side of his signal. I instantly noticed a hissing sound that coincided with the transmitted dashes. Five kHz off the test frequency the hissing dashes were S5; 10 kHz away, the dashes were S2; 15 kHz away, the dashes were just above the noise level. We didn't try adding the linear amplifier to the tests because we wanted to examine only the exciter.

We now reversed the tests. My friend listened to my transceiver as I keyed it slowly. Sure enough, the same white noise was heard, even though the transmitters were of differ

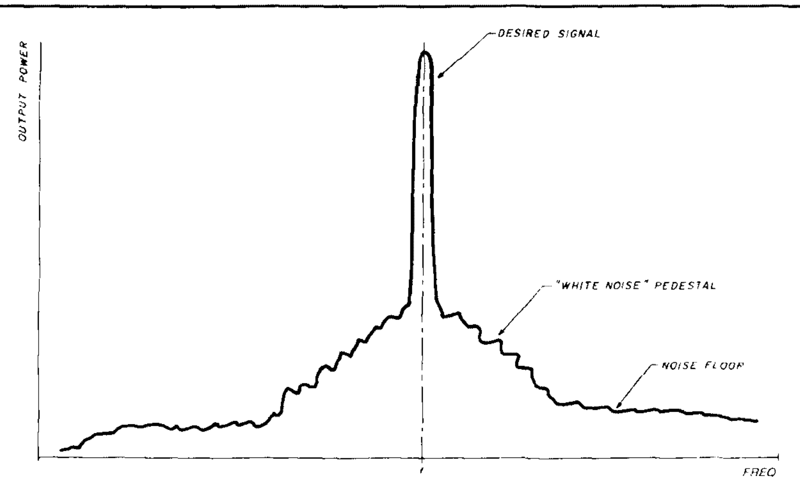


fig. 1. "White noise" generated by PLL frequency control device.

ent manufacture. I next cut out my external VFO (a PLL device) and cut in the internal VFO, which did not use PLL. I could thus test one frequency generation scheme against another at the push of a button. Using the internal VFO, the white noise disappeared immediately! My carrier was squeaky-clean right up to my S9 plus 30-dB signal with no apparent sideband noise.

As an afterthought, my friend switched on his linear amplifier and keyed the transmitter. Alas, the hissing noise came up over an S-unit and was now apparent over nearly 100 kHz on each side of the main carrier.

What was the culprit? Most communications specialists believe the problem lies in the synthesizer technique, but instances have occurred in which white noise was generated in the solid-state final amplifiers of some equipment. It could also be mixing noise in some of the transmitter stages.

Amateurs in the western states well remember when a Voice of America transmitter operating on 21460 kHz switched over from crystal control to a frequency synthesizer. The whole top end of the 21-MHz band was obliterated by white noise, which was reported by Amateurs in South America as being over S9! The problem was finally resolved when the synthesizer was removed from service.

Talking to close friends who have some expertise in the subject indicates that transmitted white noise varies not only from make to make, but model to model, and from unit to unit of PLL-controlled transmitters. Thus no specific make or model transmitter can be cited as being the main cause of the difficulty. The problem is much more complex than that.

the solution?

The solution lies in the design of the synthesizer, as well as the lead dress and filtering. What is required is the establishment of ground rules that define the amount of white noise acceptable for a given transmitted power level — just as in military gear. The problem of receiver overload seemed formidable a decade ago, but over the past few years it has been solved by the efforts of the equipment manufacturers. As to white noise, let's hope the same path will be followed. The first order of business is to recognize the problem; the next is to ascertain its magnitude. Does it affect only a few Amateurs? Or is it a more widespread problem, the cause of which has simply not yet been revealed to the general body of operators? I'll appreciate any comments that Amateurs may have regarding this subtle problem.

160-meter DX season — back again!

Hooray! The blasting summer static has dropped off in the Northern Hemisphere and Happy Days Are Here Again on 160 meters. Shown in **fig. 2** is a top-loaded vertical antenna used by some operators who are trying to be loud even though they live on small lots. In most cases, it's made of wire and slung between two trees. The 40-foot vertical wire is attached to the midpoint of an 80-foot wire which serves as the top loading structure. The antenna is worked against ground, and resonated to the operating frequency by means of the series-connected rotary inductor. The feedpoint resistance depends upon the ground resistance, as is the case with any Marconi-type antenna. With a ground system consisting of a ground rod, or connection to the cold water pipe system of the dwelling, plus two or three quarter-wave radials, the feedpoint resistance will run about 20 ohms. A simple L-network may be required between the coax feed line and transmitter to drop the SWR to a low enough value to permit an easy match to today's modern solid-state equipment.

With regard to the ground system for a 160-meter Marconi-type antenna, Mitch, KB6FPW, has some interesting experiences to relate. He erected an inverted-L antenna (imagine the antenna of **fig. 2** with half the top wire removed). The wire was cut to a total length of 3/8 wavelength at 1.9 MHz. Most of the wire was in the horizontal plane.

His first rf measurements, using water pipe grounds, showed a feedpoint resistance of 100 ohms. Addition of a 4-foot ground rod and a quarter-wave radial wire, wrapped around the perimeter of a fence and terminated in another 4-foot ground rod, brought the feedpoint resistance down to about 50 ohms. Mitch next added several extra radials of various lengths and a third ground rod. The feedpoint resistance dropped to 40 ohms. A second quarter-wave radial wrapped

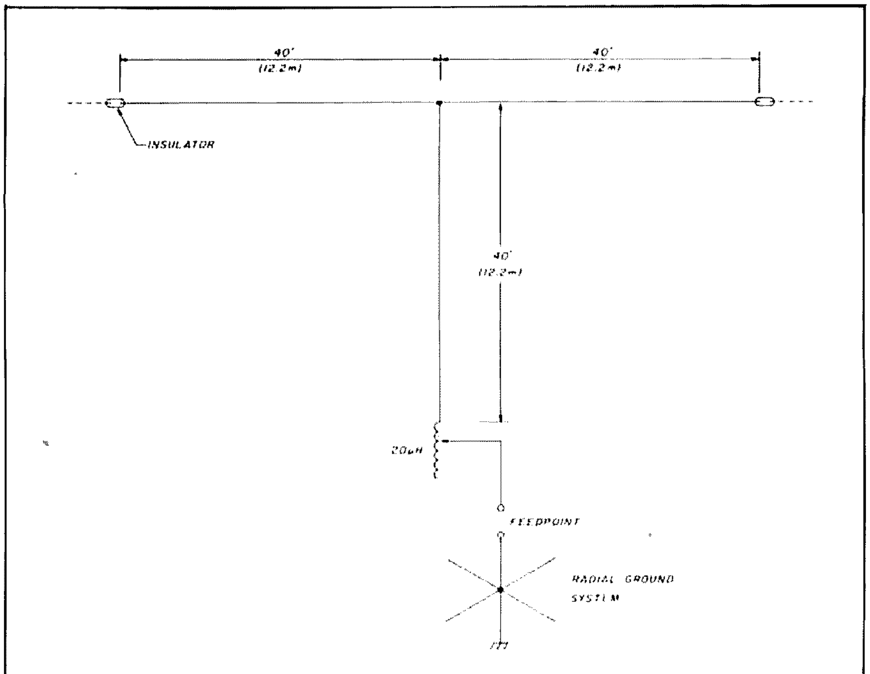


fig. 2. Compact T-antenna for 160 meter operation.

around the house didn't seem to make an appreciable difference. Mitch figured he had reached the point of diminishing returns, and there the experiment ended.

Mitch says, "There is a common misconception about ground radials. It's often said that a quarter-wave radial looks like a low impedance at the input end. If a short circuit (to ground) was applied to the far end of the radial, a high impedance would be reflected back to the input end. In free space this may be true, but when the radial is brought in close proximity to the ground, significant coupling exists — enough to change the character of the radial. Terminating a quarter-wave radial, laid close to the earth, with a ground rod at the outer end does not reflect a high impedance back to the input end. Instead, it improves the efficiency of the radial and actually lowers its impedance.

"Electrically short radials depend upon proximity with the earth. I have performed experiments on 1750 meters with a 100-foot radial. When the wire was held clear of the ground (at about 4 or 5 feet elevation), the radial current was unmeasureable with a 100-mA rf ammeter. As the radial was lowered to the earth, the radial current climbed to a maximum figure of 8.5 mA."

Mitch, by the way, is conducting experimental VLF transmissions using the identifier MEL on 170.626 kHz.

feedback from the field?

Great interest is expressed by newcomers to the 160-meter band: "What antenna should I use?" "What do the outstanding signals on the band use for antennas?" I'd like to hear from readers who have 160-meter antennas that work, and that may not be the common variety shown in all the handbooks. If you have an interesting antenna, write to me at: EIMAC, 301 Industrial Way, San Carlos, California 94070. Many thanks!

references

1. Doug DeMaw, W1FB, and Wes Hayward, W7ZOI, "Modern Receivers and Transceivers: What Ails Them?," *QST*, January, 1983, page 12.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

microwave and millimeter-wave update

Time really flies. Would you believe this month's column marks the beginning of the fourth year for "VHF/UHF World?" I'd like to thank those of you who have sent in such nice comments and ideas for future columns.

When I first started this column, I had about 15 possible topics outlined. Even though three years have gone by, that list is as long as ever. I'm always looking for constructive suggestions. Any ideas about subjects that need to be addressed or amplified? Just drop me a note. Your letters are always appreciated — even if I don't have time to answer them all.

About half of last year's columns were primarily oriented towards microwave and millimeter-wave subjects. This year I expect to continue in that vein. I hope I can keep the column well enough in balance so that all readers will be satisfied!

microwave and millimeter-wave update

North Americans were pioneers on the microwave and millimeter-wave bands, first with pulse and then "polaplexers."[1] However, in recent years we fell behind, especially in respect to our European colleagues. Most of the activity and DX records on these frequencies are presently held by Europeans. Even the "Gunnplexers" manufactured in the United States are being used in Europe to set new worldwide DX records!

We reviewed the general topic of microwaves in the January, 1986, column,[1] looking at available frequencies, DX records, microwave receivers, transmitters, antennas, feedlines, and schemes for getting on the frequencies above 70 cm (450 MHz). Little did I know that 1986 would be such an explosive year for microwave and millimeter-wave growth in North America. Although none of the worldwide DX records held outside North America were reclaimed in 1986, many of the North American DX records were broken.

For starters, the 33-cm (903 MHz) DX record was extended — but this was to be expected because this band had been available to Amateurs for less than a year. K3YTL and W1JR held the record for just under one day (June 15, 1986); then K1WHS and K3YTL snatched the record! I expect that there will be several 33-cm DX extensions per year for the next several years as gear improves and activity increases.

The North American 23-cm (1296 MHz) tropo DX record was broken this past summer when KH6HME and WB6NMT spanned the Pacific. This record still stands worldwide and will be very difficult to extend much further!

Soon after the DX records were published in the January, 1986 column, the 13-cm (2304 MHz) North American tropo DX record was broken when W4ODW and WB5LUA caught one of those great openings that occur in the Gulf area early each year. They extended this DX record by about 40 miles.

The North Texas Microwave Society, after a real onslaught on the 13-cm band in 1985, decided to push higher in 1986 and challenge the 16-year DX record on the 9-cm (3456 MHz) band. It didn't take them very long; less than three months after they activated this band, one of the longest-standing North American DX records fell when WA5TNY/5 (portable) worked W7CNK/5, a fixed station in Oklahoma City, Oklahoma, for a new North American DX record of 221 miles. The QSO first took place on cw and then on two-way SSB.

The 6-cm (5650 MHz) North American DX record is now under fire by a hotbed of activity centered in northeastern Oklahoma. It looks as if this 9-year old DX record will soon be broken. Some one-way contacts have already exceeded the present 267-mile DX record on this band.

Finally, in the Pacific northwest, one of the first regions of the world to develop microwave activity and set DX records, the 12-mm (24 GHz) North American DX record has recently been extended by over 50 percent to 115 miles by WA3RMX/7 and WB7UNU/7. This record is rather unusual in that it was accomplished not only with very low power (20 milliwatts maximum), but with narrowband modulation. First the record was set on cw and then continued using two-way SSB — perhaps the highest frequency where two-way SSB communications has ever been used by Amateurs, and perhaps even commercial interests as well.

Yes, 1986 was an exciting year for microwave and millimeter-wave activity, especially in North America. At long last it looks as if North Americans are again going to be in the forefront of activity and development on one of our highest frequency allocations.

To show the latest North American and worldwide VHF and above DX records, I've revised the tables published in references 1 and 2. **Table 1**

1. This table shows the latest claimed North American DX records on the frequencies above 6 meters. Note that the records are shown alphabetically by propagation modes. (Updated October 12, 1986.)

Frequency	Record	Date	Prop. Mode	DX miles	(km)
50 MHz	Note 2				
144 MHz	KA1ZE-WB0DRL	86-02-08	Aurora	1347	(2167)
	KH6GRU-WA6JRA	73-07-29	Ducting	2591	(4169)
	VE1UT-VK5MC	84-04-07	EME	10,985	(17676)
	W4EQR-W7HAH	81-07-09	Es	1881	(3027)
	W5HUQ/4-W5UN	83-07-25	FAI	1229	(1977)
	K5UR-KP4EKG	85-12-13	MS	1960	(3153)
	KP4EOR-LU5DJZ	78-02-12	TE	3933	(6328)
	K1RJH-K5WXZ	68-10-08	Tropo	1465	(2358)
220 MHz	W3IY/4-WB5LUA	82-07-14	Aurora	1145	(1842)
	KH6UK-W6NLZ	59-06-22	Ducting	2550	(4087)
	K1WHS-KH6BFZ	83-11-17	EME	5058	(8139)
	K1WHS-KOALL	85-08-12	MS	1274	(2049)
	KP4EOR-LU7DJZ	83-03-09	TE	3670	(5906)
	VE3EMS-WB5LUA	82-09-28	Tropo	1181	(1901)
432 MHz	W3IP-WB5LUA	86-02-08	Aurora	1182	(1901)
	KD6R-KH6IAA/P	80-07-28	Ducting	2550	(4103)
	K2UYH-VK6ZT	83-01-29	EME	11,567	(18612)
	W2AZL-W0LER	72-08-12	MS	1020	(1641)
	WA2LTM-WB5LUA	79-09-10	Tropo	1310	(2108)
903 MHz	K1WHS-K3YTL	86-06-16	Tropo	310	(498)
1296 MHz	KH6HME-WB6NMT	86-08-13	Ducting	2528	(4068)
	K2UYH-VK5MC	81-12-06	EME	10,562	(16995)
	W4WSR-WA5TKU	85-06-03	Tropo	1112	(1790)
2304 MHz	PA0SSB-W6YFK	81-04-05	EME	5491	(8836)
	W4ODW-WB5LUA	86-02-20	Tropo	628	(1003)
3456 MHz	WA5TNY/5-W7CNK/5	86-08-03	Tropo	222	(357)
5760 MHz	K5FUD-K5PJR	77-09-20	Tropo	267	(430)
10.368 GHz	WA4GHK/4-WD4NGG	84-08-07	Ducting	297	(478)
	W7JIP/7-W7LHL/7	60-07-31	LOS	265	(426)
24.192 GHz	WA3RMX/7-WB7UNU/7	86-08-23	LOS	115.5	(186)
48 GHz	W2SZ/1-WA2AAU/1	84-09-08	LOS	0.3	(0.5)
76-149 GHz	None reported				
474 THz	K6MEP-WA6EJO	79-06-09	LOS	15	(24)

Note 1. The records are listed alphabetically by mode. Ducting is suspected where the path is mostly over water. No efforts are made to separate out ducting on overland paths so they're grouped under tropo.

Note 2. Six meter records were left off since the primary mode is often hard to distinguish. Also long-path QSOs have been reported during solar cycles 19 and 21 which exceed 12433 miles (20004 km).

shows the latest North American DX records on the bands above 50 MHz. **Table 2** shows the equivalent updated worldwide DX records. **Table 3** shows the worldwide EME DX records. Will the data in **Table 1** become obsolete before the end of 1987? I'll bet on it!

why the increased activity?

1986 was a banner year for the microwave and millimeter-wave bands primarily because North American microwave enthusiasts gathered together, organizing societies and conferences and pooling their interests and resources. New DX records were also on their minds. Until recently, the modulation for most North American microwave and millimeter-wave operation was fm or cw using a keyed multiplier chain. Fm requires a good signal-to-noise ratio and moderate to wide bandwidth. Keyed multipliers aren't always that stable, especially if operated in remote locations such as mountaintops.

For reliable communications, and especially DX, you need good frequency stability in the transmitter as well as in the receiver. Narrow bandwidth modulations such as cw and SSB are preferred. Also important are low noise figure receivers, reasonable transmitted output power, moderate- to high-gain low-noise antennas, and low insertion loss feedlines. All these factors had to be addressed if real progress was to be forthcoming.

The same Amateurs who recently activated the microwave bands were also spurred on by the desire to use some of the new state-of-the-art technology that has recently become so affordable. After designing and building this new equipment, they organized mobile stations to travel to DX locations and to aid in activating new "grids" for the ARRL VUCC (VHF/UHF Century Club) award.

equipment considerations

If you want to take advantage of cw and SSB with its improved higher signal-to-noise ratio, you must pay close attention to frequency stability. Receiver/transmitter frequency stability objectives can best be met on the microwave/millimeter-wave bands by using solid-state up/down converters or transverters.

Many homebrew as well as commercial designs are now on the market. Modern solid-state transceivers are now available through 1300 MHz and are often used as the transmit/receive i-f for these same converters/transverters. The combination of

2. This table shows the latest claimed worldwide terrestrial DX records for the Amateur bands above 6 meters.

Frequency	Record Holder	Date/QSO	Prop.Mode	DX miles	DX (km)
50 MHz	Note 1.				
70 MHz	GW4ASR/P-5B4CY	81-06-07	Es	2153	(3465)
144 MHz	I4EAT-ZS3B	79-03-30	TE	4884	(7860)
220 MHz	KP4EOR-LU7DJZ	83-03-09	TE	3670	(5906)
432 MHz	KD6R-KH6IAA/P	80-07-28	Tropo duct	2550	(4103)
903 MHz	K1WHS-K3YTL	86-06-16	Tropo	310	(498)
1296 MHz	KH6HME-WB6NMT	86-08-13	Tropo duct	2528	(4068)
2304 MHz	VK5QR-VK6WG/P	78-02-17	Tropo duct	1170	(1883)
3456 MHz	VK5QR-VK6WG	86-01-25	ducting	1171	(1885)
5760 MHz	G3ZEZ-SM6HYG	83-07-12	ducting	610	(981)
10 GHz	I0SNY/EA9-I0YLI/IE9	83-07-08	ducting	1032	(1660)
24 GHz	I3SOY/3, IW3EHQ/3-I4BER/6, I4CHY/6	84-04-25	LOS	180	(289)
47 GHz	HB9AMH/P-HB9MIN/P	85-01-13	LOS	31.7	(51)
75 GHz	HB9AGE/P-HB9MIN/P	85-12-30	LOS	0.3	(0.5)
474 THz	K6MEP-WA6EJO	79-06-09	LOS	15	(24)

Note:
1. Six meters has been left blank on this listing because long-path QSOs (those exceeding 12440 miles or 20016 km) have been reported during solar cycles 19 and 21.

3. This table shows the latest claimed worldwide EME DX records.

Band	Record Holder	Date/QSO	Prop.Mode	DX miles	DX (km)
50 MHz	K6MYC-K8MMM	84-07-24	EME	2127	(3422)
144 MHz	K6MYC/KH6-ZS6ALE	83-02-18	EME	12088	(19450)
220 MHz	K1WHS-KH6BFZ	83-11-17	EME	5058	(8139)
432 MHz	F9FT-ZL3AAD	80-04-18	EME	11679	(18793)
903 MHz	none reported				
1296 MHz	PA0SSB-ZL3AAD	83-06-13	EME	11595	(18657)
2304 MHz	PA0SSB-W6YFK	81-04-05	EME	5491	(8836)

3300 MHz and above: None reported.

a stable solid-state converter/transverter and i-f will produce stable operation on CW and SSB. It also permits moderate to narrow i-f bandwidth and its commensurately better signal-to-noise ratio is especially desirable for receiving weak signals. Finally, this combination will usually be more reliable and small to moderate in size, making it a good choice for portable operations, especially from high elevations free of local obstructions.

conversion schemes

Before you start to design and build microwave and millimeter-wave gear — especially if you want to advance the state of the art — you should first develop an overall plan of attack. Foremost in that plan is choosing the frequency conversion scheme, which is very important because it affects cost, complexity, performance, and future flexibility.

The first step is to identify the generally accepted weak-signal microwave operating frequencies. Those for 13-cm and above were set up many years ago as multiples of 1152 MHz, as discussed in reference 1. These frequencies, as well as the generally accepted frequencies on the lower microwave bands, are shown in **table 4**.

Note that since the microwave frequency plans were originally established, some slight modifications have been made to accommodate EME. EME operation is now centered around this frequency with a guard band of at least ±50 kHz. In North America it is now standard operating practice to use the frequency 100 kHz above the old operating or EME frequency for the terrestrial cw/SSB calling as shown on

4. Typical North American weak-signal microwave operating and calling frequencies for EME and terrestrial operation.

Band (cm)	EME center frequency (MHz)	Weak-signal calling frequency (MHz)
33	903.0	903.1
23	1296.0	1296.1
13	2304.0	2304.1
9	3456.0	3456.1
6	5760.0	5760.1
3	10368.0	10368.1

table 4. Calling frequencies are great for finding activity, especially in areas where activity is low.

Next, if possible, choose a conversion scheme that will allow at least 15-20 dB of image rejection with simple filtering. If a low-frequency i-f is chosen (for example, 28 or 50 MHz), the rf filtering ahead of the first mixer will be more stringent, since the image frequency will be close to the rf frequency. This usually requires a narrow bandwidth filter, possibly with more than one pole. This type of bandpass filter is often more difficult to tune and may have higher insertion loss than a simple one-pole type.

Different i-f and LO (local oscillator) schemes are in use on the microwave bands, as discussed in reference 1. Nowadays a 2-meter i-f is most popular for the 23- and 13-cm bands. Therefore, an 1152- and 2160-MHz LO would be required for 1296- and 2304-MHz transverter operation, respectively, as shown in **figs. 1A** and **1B**.

Interestingly enough, if you use these schemes, you can get on 3456 MHz almost for free. Simply mix the output of your 1296-MHz transmitter with the 2160-MHz LO and *voila!* — you have 3456 MHz, as shown in **fig. 1C**. This is the scheme used by many of the operators now on 9 cm.[3]

If you use this scheme and a TVRO-type (3.7-4.2 GHz) preamplifier, you get sufficient image and LO rejection for free. This is true because the image frequency is 864 MHz and the LO is 2160 MHz, well below the cutoff frequency of the waveguide typically used on TVRO-type preamplifiers.

Paul Shuch, N6TX, recently extended this technique to the 6- and 3-cm (10,368 MHz) bands.[4] His approach is more or less an offshoot of the 1152-MHz multiplier scheme described in reference 1.

Basically it goes like this. If you multiply the 1152-MHz LO three times and mix it with 2304 MHz, you get 5760 MHz (**fig. 1D**). Now if you also multiply the same 1152-MHz LO seven times and mix it with 2304 MHz, you get 10,368 MHz (**fig. 1E**).

Furthermore, if you don't care about the lower microwave bands, just multiply the 1152-MHz LO seven times and mix it with 2304 MHz. You'll get both 5760 and 10,368 MHz from a typical mixer. If an image rejection mixer is used, you'll have instant separation of the two desired outputs (**fig. 1F**).[5]

These conversion techniques all have their advantages and disadvantages, depending on the bands you want to work and the gear you have. If the frequencies specified in **table 4** are maintained, fewer LOs will be required to get on the microwave bands. This is significant because frequency instability is one of the biggest impediments to reliable microwave and millimeter-wave communications.

For over a decade 3-cm ("X" band) GunnPlexers have been in use. Various i-fs (such as 30, 50, and 88-108 MHz) have been used. The majority of stations in North America now seem to favor 30 MHz. The two most popular frequencies chosen for this scheme are 10,250 and 10,280 MHz, well away from the weak-signal calling frequency.

mixer design

Anyone familiar with my designs is well aware of how much I favor the

use of DBMs (double-balanced mixers) for up/down converters.[6] I feel even more strongly that, if available, they should be used in the microwave region. DBMs have fewer spurious outputs and usually are matched to 50 ohms at all ports, so they're easy to use with standard 50-ohm filters and amplifiers.

Many suppliers manufacture DBMs for the VHF/UHF bands, but the choices narrow as you go above 1 GHz, especially if price is any consideration — as it always is for us Amateurs! Once again, we're helped by the TVRO business, which has generated some reasonably priced DBMs that cover both the 9- and 13-cm bands.

Table 5 shows typical specifications of some reasonably priced (less than $100) DBMs that are usable through 4.2 GHz. Be careful in your selection, because the upper limit of the i-f is not always high enough for some of the higher i-f conversion schemes just discussed.

Until moderately priced DBMs are available above 4.2 GHz, Amateurs will probably have to use single-balanced or single-ended mixers for the upper microwave and millimeter-wave bands. At 3 cm and above, waveguide mixers are readily available on the surplus market. Even some of the police radar detection mixers may be adaptable to Amateur operation.

Finally, don't overlook GaAsFETs as mixers. They may be more difficult to use than DBMs and may require additional filtering or tuning, but they can be much less expensive than DBMs. Single-gate GaAsFETs are usable, but the dual-gate types are a natural for mixers because the LO can be injected directly into the second gate. Furthermore, GaAsFET mixers often have conversion gain and hence require less follow on gain, an especially important consideration in transmitter applications.

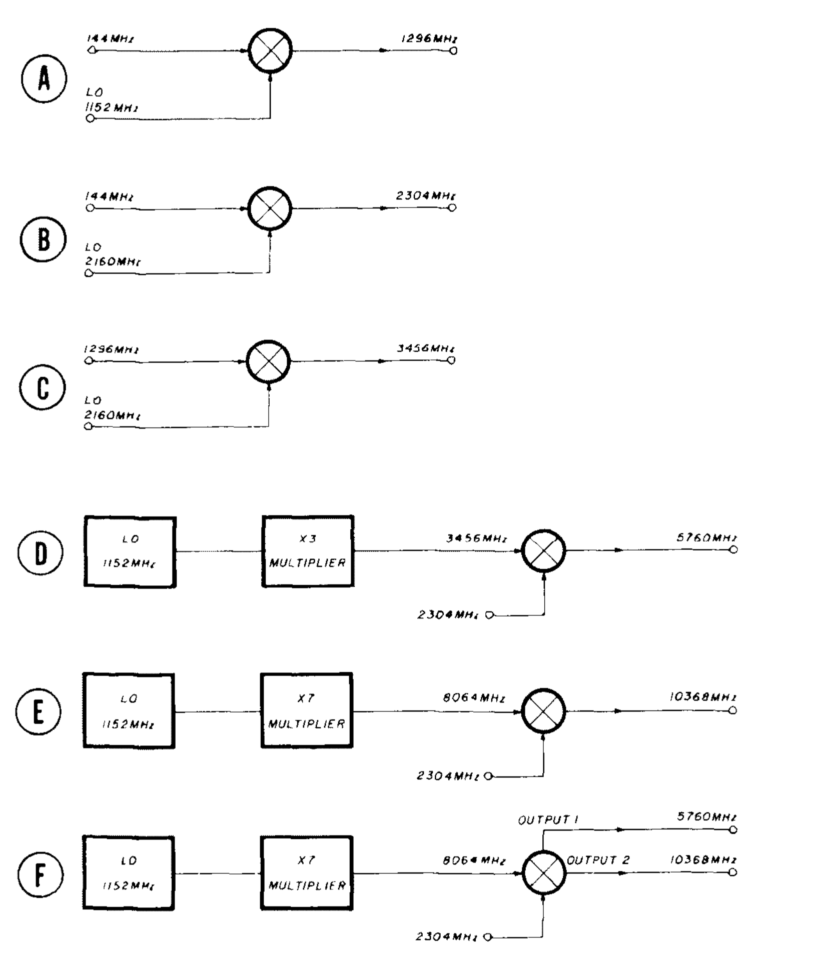


fig. 1. These are some of the popular or recommended conversion schemes for getting on the Amateur microwave bands. In all cases, the frequencies shown will place you near the most common operating frequencies listed in table 4. (See text for explanation of figs. 1A through 1F.)

local oscillators

Local oscillators are a subject unto themselves. Many circuits have been published; the most successful ones used on the microwave bands have been those that started with a fifth or seventh overtone crystal oscillator operating in the 90-125 MHz region followed by a transistor multiplier.[5,6]

Often a 96-MHz oscillator is multiplied 12 times to 1152 MHz as just discussed. Transistor or diode multipliers can be used if a high frequency (for example, 2160 MHz) is desired.[7,8] For the most critical applications, especially for the upper microwave and millimeter-wave bands, oven-stabilized oscillators may be preferred.

Recently several packaged oscillator/multipliers appeared on the surplus market; often they can be retuned to the Amateur bands. Some even use internal phase-locked oscillators. Several commercial sources are now available to the Amateur (more on this later), so I won't dwell on this subject at this time.

low-noise preamplifiers

Only a decade ago receivers using crystal mixers in the front end were in common use. They still are used today in GunnPlexers. Receivers with a mixer as the first active stage frequently have noise figures of 8-10 dB or even higher!

If you want to take advantage of cw and SSB communications, you should design your receiver accordingly. Low noise figure preamplifiers and designs are now quite plentiful, especially since

Table 5: Some recommended "standard level" (5 milliwatts LO) DBMs that will work on the microwave frequencies and cost less than $100.00.

Part No.	Supplier	rf/LO freq GHz	i-f freq GHz	Conv.loss typ.dB	Price ea.	Notes
DBM-500	Vari-L Company	1.7-4.2	DC-1.5	7.5	95.00	w/SMA connectors
DBM-1120	Vari-L Company	1-2	DC-0.8	5	85.00	w/SMA connectors
PAM-42	Mini-Circuits	2-4.2	DC-1.3	7-8	26.95	module
SRA-5	Mini-Circuits	.05-1.5	DC-0.6	7-8	21.95	relay can
ZAM-42	Mini-Circuits	1.5-4.2	DC-0.5	7-8	39.95	w/SMA connectors
ZFM-4212	Mini-Circuits	2-4.2	DC-1.3	7-8	39.95	w/SMA connectors

low-cost GaAsFETs became available.[9] Low-cost GaAsFETs can now yield noise figures under 2 dB through 25 GHz, which is more than sufficient for terrestrial communications!

TVRO preamplifiers without modifications seem to work quite well on the 9-cm Amateur band and deliver 40-55 dB of gain with a typical noise figure of 1.5 dB. All they require is a waveguide-to-coax transition on the input and dc power applied directly to the unit or through the feedline if so configured. They're often available at flea markets for less than $30!

transmitter amplifiers

CW or SSB with narrow bandwidth i-fs and good frequency stability make microwave and millimeter-wave DX very feasible using low power (less than 1 watt), as discussed previously. The use of a low-level upconverter with a DBM is becoming very popular even in the microwave region.[10] The rf output power available from a "standard" level DBM is typically in the 10-100 μwatt region. Therefore, this approach normally requires 25-50 dB of gain to reach a reasonable transmitter output power level.

Inexpensive gain (at $2-4 per device) is now readily attainable by the use of MMICs (monolithic microwave integrated circuits). Many devices are available up through at least 6 GHz, with output powers approaching 100 milliwatts.[7,11] The MMIC will probably be the workhorse for power levels below 100 milliwatts.

GaAsFETs are particularly attractive for transmitter applications since they're low in cost and have high gain. Even the small-signal types can usually deliver 10-100 milliwatts of output power.

Microwave class C power bipolar transistors and GaAsFETs — especially the "internally" matched types — are also usable, especially if only cw operation is contemplated. They are less costly than linear types with higher power levels (5 to 10 watts or more).

Linear types of bipolar and GaAsFETs that can deliver 2 to 5 watts are also available. These devices are expensive ($100 to $300), but offer considerable performance and size advantages when compared to conventional power generation techniques. Prices of these devices are constantly dropping.

One of the real sleeper bargains is the TWT (Traveling Wave Tube). Expensive only if it's purchased new, it provides very high gain (typically 25-40 dB), usually over an octave of bandwidth into 50 ohms — without external tuning! Two-to 4-GHz TWTs are quite common and cover two Amateur microwave bands for the price of one!

Available through 25 GHz and usually moderate in size (typically only 6 to 12 inches long), TWTs are generally linear amplifiers. Transmitter-type TWTs that deliver up to 100 watts of output power at 10 GHz are also available!

TWTs do require several different voltages, often up to or above 1000 volts, with a positive ground. They can be used for portable operation if 115 VAC is available either locally or from a small gasoline generator or a dc-to-ac inverter.

Don't overlook receiver-type TWTs, which also have high gain and typically deliver 1-10 milliwatts of maximum output power, more than adequate for low-power operation. However, they're not recommended for front ends on receivers because they usually have 5-10 dB noise figures.

TWTs have been used in satellites and point-to-point microwave links for many years. However, the trend is to use solid-state amplifiers because they require only a few low voltages and are very compact. Furthermore, some of the TWTs used by telephone companies are being replaced by solid-state-amplifiers. As a result, TWTs are finding their way into the Amateur surplus market, especially for the 6- and 9-cm Amateur bands.

Below 3.5 GHz, the ubiquitous 2C39/7289 vacuum tube family is still usable. Twenty-five to 50 watts output per tube has been reported on 13 cm. Power klystrons that deliver hundreds of watts are also available for the microwave frequencies if you're fortunate enough to locate them, but that's another ball game.

antennas and transmission lines

Antenna designs have also come a long way in recent years. The principal workhorse of the microwave bands is the parabolic dish, although the loop Yagi has been used as high as 10 GHz.[12,13,14]

The real bargains are the used or surplus UHF TV and TVRO dishes. Channel Master makes a 7-foot UHF TV dish which, when covered with proper screening, works well up through 13 cm.[13,15]

Feeding dishes isn't too complicated for terrestrial work. Two 3-pound coffee cans soldered together using a quarter-wave probe works well at 23 cm.[15] A similar arrangement using a one-pound coffee can will cover 13-cm[15] while a Campbell's soup can makes a good feed on 9 cm.[7]

Recently scalar feeds such as the TVRO "Chaparral"™ type are being used. They seem to work well on the lower F/D (0.35-0.4) dishes.[12,13] When this feed is used on the larger diameter (6 foot minimum) dishes on the 9-cm Amateur band, the overall gain seems to be very near the expected value.

Feedlines are always a problem on the microwave bands. Low dielectric foam or air dielectric Heliax™ used in the shortest possible length are recommended.[16] The popular trend on the microwave bands is to use antenna-mounted preamplifiers and to locate the transmitter as close to the antenna feed as possible. This is increasingly more feasible when solid-state devices are used in the transmitter. Low-loss waveguide feedline is recommended on 10 GHz and above.

commercial gear

As previously mentioned, there are now commercial converters, transverters, and LOs available for all the Amateur bands through 13 cm. SSB Electronics uses a very interesting packaging concept. Each of their subsystems is a separate module. For instance, for a transverter you buy a separate LO with dual outputs, receive downconverter, and transmit upconverter. The LO for a 13-cm setup is a compact unit that puts out a stable 3-5 milliwatts of power at 2160 MHz for about $100. This unit can be adapted to the 9-cm scheme mentioned earlier.

Recently SSB Electronics announced a 3-cm (10,368 MHz) transverter that sports a 2.5-dB maximum receiver noise figure and over 150 milliwatts of output on CW or SSB. A 144-MHz i-f is used. The filtering required is obtained by the use of several dielectric resonators that have very high Q and low insertion loss. At less than $500 for the basic transverter, this should be a natural for weak-signal "X" band enthusiasts.

*Transverters Unlimited, Hans Peters, VE3CRU, Box 6286 Station A, Toronto, Ontario, Canada M5W 1P3.

propagation

This subject was discussed in detail earlier.[2,17] It's quite obvious from the details already discussed on new North American DX records that the microwave and millimeter-wave Amateur enthusiasts are taking advantage of many of the radio propagation opportunities available to them. Once again this proves that these are very worthwhile frequencies, quite capable of supporting radio propagation well beyond the line of sight!

summary

This month's column was primarily aimed at updating all the recent happenings on the microwave and millimeter-wave bands and in particular the recent record breaking DX contacts. It's great to see such activity and advancement of the state of the art.

Some of the latest techniques and devices that are presently being used were also discussed. It's good to see that Amateurs are really taking advantage of the new low- to moderately-priced solid-state devices, and nice to see Amateurs benefit from the UHF and TVRO businesses. It's no longer very difficult to build or operate gear on our highest Amateur bands.

Important VHF/UHF Events:

January 3:	*Predicted peak of the Quadrantids Meteor Shower at 1830 UTC.*
January 10-12:	*ARRL VHF Sweepstakes Contest*
January 28:	*EME perigee*
February 25:	*EME perigee*

references

1. Joe Reisert, W1JR, "VHF/UHF World: Amateur Microwave Bands," *ham radio*, January, 1986, page 44.
2. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-Wave Propagation: Part 1", *ham radio*, July, 1986, page 82.
3. Rick Fogle, WA5TNY, "3456 MHz Operation," *Proceedings of the 1986 Central States VHF Conference*, St. Louis, Missouri, July, 1986.
4. Paul Shuch, N6TX, "A Five-Band Microwave Transverter," *Proceedings of the Microwave Update 86 Conference*, Estes Park, Colorado, August, 1986.
5. Joe Reisert, W1JR, "Getting Started on 13 and 23 cm", *Proceedings of the 1985 1296/2304 MHz Conference, Estes Park, Colorado, September, 1985.*
6. *Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Receivers," ham radio*, March, 1984, page 42.
7. Al Ward, WB5LUA, "MMIC Update/Cascading

MMIC's," *Proceedings of the Microwave Update 86 Conference*, Estes Park, Colorado, August, 1986.
8. Richard L. Campbell, KK7B, "A Clean Microwave Local Oscillator," *Proceedings of the 1985 1296/2304 MHz Conference*, Estes Park, Colorado, August, 1985.
9. Joe Reisert, W1JR, "VHF/UHF World: Low-Noise GaAsFET Technology," *ham radio*, December, 1984, page 99.
10. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Exciters," *ham radio*, April, 1984, page 84.
11. Joe Reisert, W1JR, "VHF/UHF World: Broadband Amplifiers in Receiver Design," *ham radio*, November, 1986, page 91.
12. Joe Reisert, W1JR, "VHF/UHF World: Reflector Antennas – Part 1," *ham radio*, February, 1986, page 51.
13. Joe Reisert, W1JR, "VHF/UHF World: Reflector Antennas – Part 2," *ham radio*, March, 1986, page 68.
14. Joe Reisert, W1JR, "VHF/UHF World: Designing and Building Loop Yagis," *ham radio*, September, 1986, page 56.
15. Gerald Handley, WA5DBY, "The Care and Feeding of a 7-Foot Dish," *Proceedings of the 1985 1296/2304 MHz Conference*, Estes Park, Colorado.
16. Joe Reisert, W1JR, "VHF/UHF World: Transmission Lines," *ham radio*, October, 1986, page 83.
17. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-Wave Propagation – Part 2, *ham radio*, August, 1986, page 69.

ham radio

NE5205 wideband amplifier

There is an error in Mike Gruchalla's article, "NE5205 Wideband Amplifier" (September, 1986, page 30). In the last few sentences of the section on performance (page 38), the 20-dB return loss is stated as being related to an impedance within 0.5 ohm of 50 ohms. This is incorrect. The port-one impedance Z_1 is given in terms of the S-parameter S_{11} by:

$$Z_1 = Z_0 \frac{(1 + S_{11})}{(1 - S_{11})}$$

The display of S_{11} in dB indicates the magnitude of the ratio of the reflected power from and the incident power to port 1. That ratio is equal to the magnitude of S_{11} squared. A 20-dB return loss is a power ratio of 1/100, which implies that the *magnitude* of S_{11} is 0.1. The two value extremes that will result in real (i.e., non-complex) values for load impedance are +0.1 and −0.1. Using the equation above and a 50-ohm characteristic impedance, the impedance corresponding to a return loss of 20 dB could be as high as 1.22 Z_0, or 61 ohms, and as low as 0.82 Z_0, or 41 ohms. So, the 20-dB return loss represents a port impedance within about 10 ohms of 50 ohms, and not 0.5 ohms as stated in the article. (TNX W3NQN — Ed.)

✓ 156

a deluxe logic probe

Accurate logic probe detects high frequencies and pulses

Plenty of good logic probe circuits have already been described in print. Unfortunately, a review of their schematics shows that each lacks something — either speed, accuracy, flexibility, or protective devices. Increasing use of microprocessors, PLL synthesizers and digital signal processing circuitry makes the need for an improved probe obvious.

The logic probe shown in **fig. 1** represents an attempt to overcome problems with existing circuits and produce a device which is simple in design and easy to construct, yet powerful and inexpensive.

circuit description

To protect the probe from an accidental reverse voltage connection, a diode is included in series with the power supply (**fig. 2**). The 1N270, a germanium diode, has a lower forward voltage drop than a silicon diode and has a peak reverse breakdown voltage of about 100 volts. The LM330T-5.0 is a low-voltage dropout voltage regulator which provides a regulated 5.0 volts output with an input as low as 5.6 volts.[1] In addition, this regulator has an approximately linear voltage output drop as the input supply voltage falls below 5.6 volts. For instance, with this device connected to a 5-volt TTL supply, its output would still be approximately 4.3 volts. The combined effects of the diode and voltage regulator are such that when the probe is connected to any supply above 6.0 volts (CMOS) the regulated output voltage V_{REG} will be 5.0 volts. When the probe is connected to any TTL supply, the voltage at V_{REG} will be about 4 volts, which is acceptable. In fact, I've found that the probe still works with an input supply voltage down around 4 volts. The 60-μF capacitor is necessary for proper regulation and should be a tantalum.

To protect the input from accidental negative or high voltage, I've used a technique similar to that used to protect CMOS gate inputs. The 2.2 k (3 watt) resistor provides current limiting when either the lower 1N914 diode conducts (negative input) or when the top 1N914 diode conducts (positive input greater than supply). The 0.068-μF ceramic capacitor provides an ac bypass for pulses.

To allow high-speed pulse detection, I've separated the pulse and level detection functions. This was necessary because most comparators have a response time far below that of most modern logic operating frequencies and therefore would reduce or miss high frequency pulses.[2] At the input, a 100-pF ceramic capacitor couples pulse signals into an MC74HC04 CMOS inverter.[3] The MC74HC04 is a HEX high-speed CMOS inverter which has an operating speed similar to that of LSTTL. In addition to low power consumption typical of CMOS, this device can be powered from

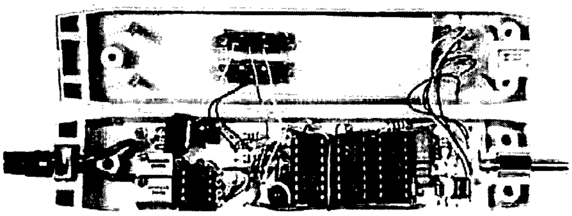


fig. 1. Deluxe logic probe.

M. Wilde, 7708-181 Street, Edmonton, Alberta, Canada T5T-127

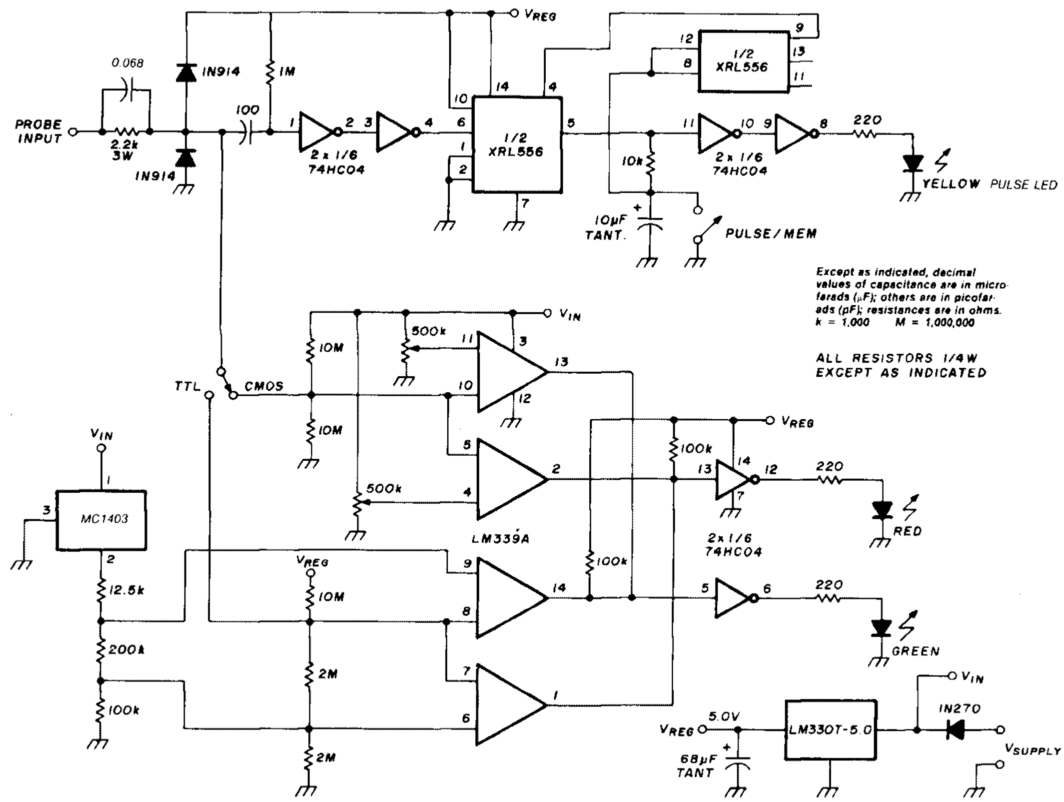


fig. 2. Logic probe schematic.

a wide range of supply voltages — 2 to 6 volts. This is useful because of the approximately 1-volt drop across the probe power supply. The 1-megohm resistor connected from the input to V_{REG} is a pullup resistor used to prevent the CMOS input from floating and erroneously triggering. The incoming pulses are put through two inverters which buffer the original pulse and square up the waveshape.

The pulse trigger and display use an XRL556 dual timer.[4] The first timer is a negative edge-triggered Set/Reset flip-flop, and the second a comparator/flip-flop. When a negative edge first appears at the input of timer 1 (pin 6), a flip-flop is set and its output goes high. This causes the pulse LED to turn on and the 10-μF capacitor to begin charging toward the supply voltage. When the voltage on this capacitor reaches 0.66 V_{REG}, the second timer turns on, resetting the flip-flop in timer 1. Now the pulse LED is turned off, and the 10-μF capacitor begins to discharge toward ground. The flip-flop in timer 1 remains reset until the decreasing voltage on the capacitor reaches 0.33 V_{REG}. At this point, timer 2's output goes low and timer 1 is ready for retriggering. Two timers provide a fixed on and off time, which will cause the pulse LED to flash on and off (at about 1 Hz) when repetitively triggered, thereby providing a pulsing display for a pulsing input. By shorting out the 10-μF capacitor, timer 2 is never allowed to reset timer 1, which provides memory.

logic level detection

Logic level detection is accomplished by two separate window detectors with their outputs ORed together. A National Semiconductor LM339 quad, single-supply comparator, which has open collector outputs is used.[5]

Two 500-k, 10-turn trim pots set to 70 percent and 30 percent of the supply voltage are used to set the CMOS thresholds. Using a 10-turn pot allows an accurate and stable setting, with the possibility of resetting these ranges to, say, 80 percent and 20 percent if it's ever necessary to detect a narrower range. Two 10-megohm resistors in series from the supply to ground hold the CMOS window comparator input to 0.5 volts V_{IN}. This keeps the logic level output LEDs off when there's no input signal. Large value resistances were chosen to reduce power consumption and provide a high input impedance.

For the TTL window detector, I used the combination of a 10-megohm resistor and two 2-megohm resistors to keep this window input at a nominal 1.1 volts (remember the approximate 1-volt drop across the

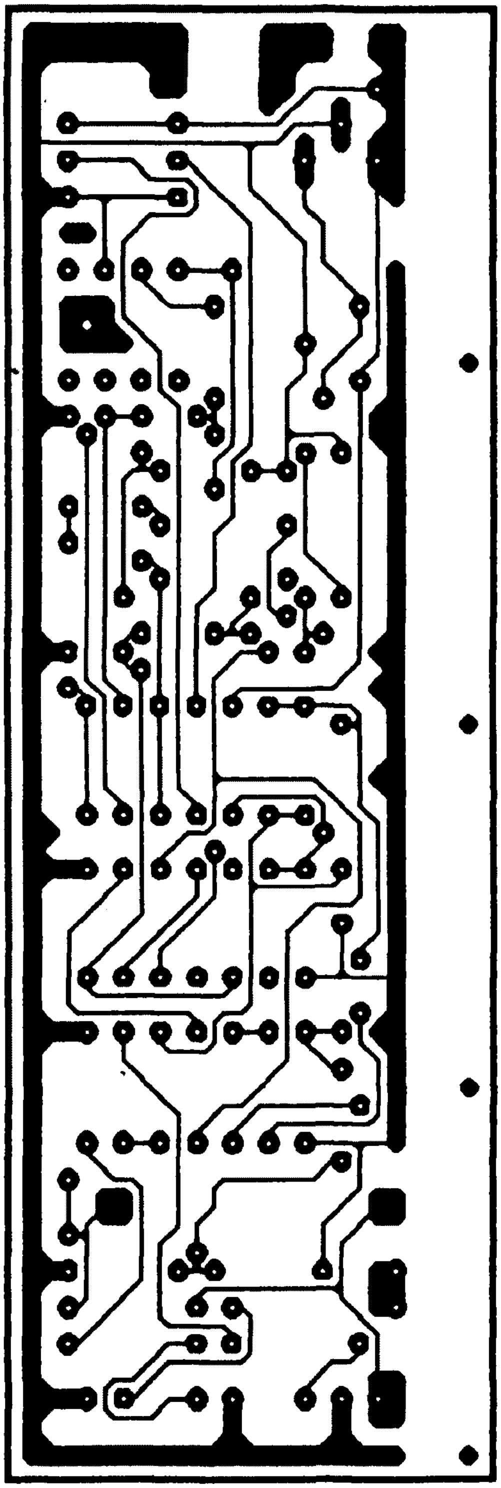


fig. 3A. Logic probe pc board artwork, shown 2x actual size.

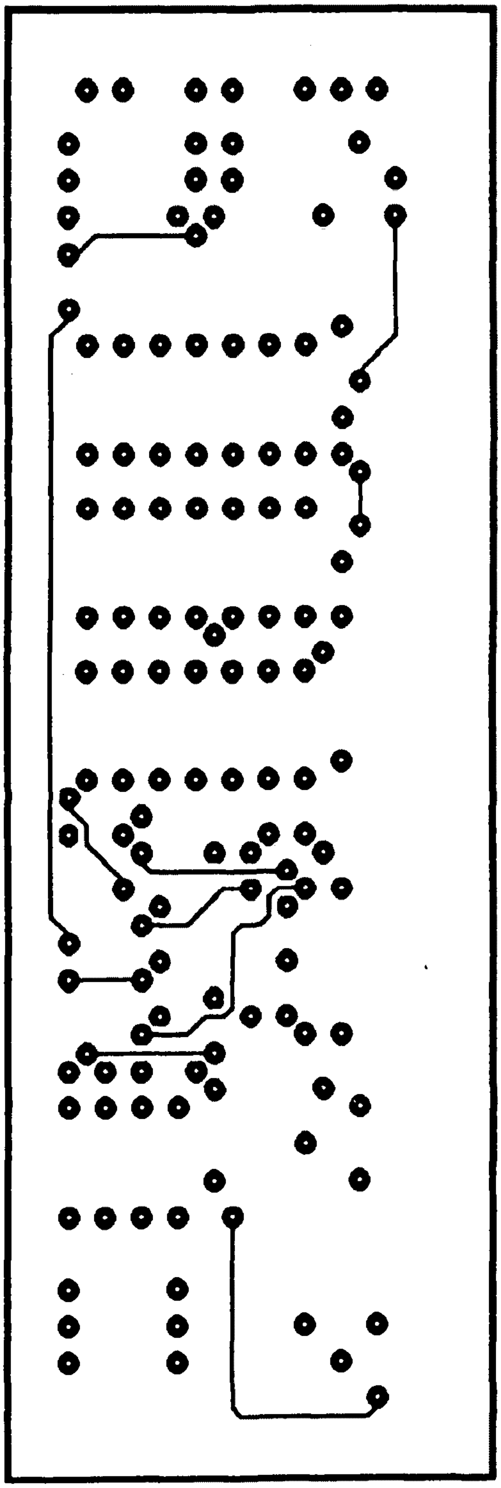


fig. 3B. Reverse side (component side) pc artwork, shown 2x actual size.

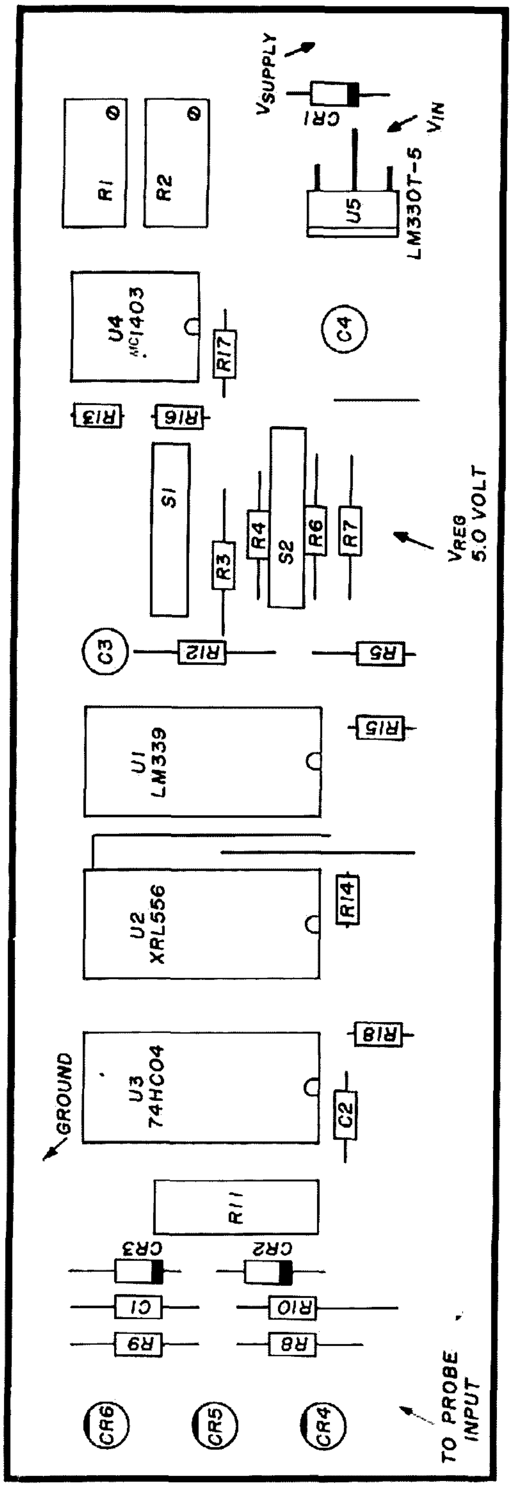


fig. 3C. Component placement diagram showing pattern of 3A, 2x actual size.

C1	*0.068 μF ceramic chip*
C2	*100 pF ceramic*
C3	*10 μF tantalum, 10 volts*
C4	*68 μF tantalum, 16 volts*
CR1	*IN270*
CR2,3	*IN914*
CR4	*LED Miniature Green*
CR5	*LED Miniature Yellow*
CR6	*LED Miniature Red*
R1,R2	*500 k, 10-turn (potentiometer)*
R3,R4,R5	*10-Megohm, 1/4-watt*
R6,R7	*2-Megohm, 1/4-watt*
R8,R9,R10	*220-ohm, 1/4-watt*
R11	*2.2 k, 3-watt*
R12	*10-k, 1/4-watt*
R13,R14,R15	*100-k, 1%, 1/4-watt*
R16	*200-k, 1%*
R17	*12.4-k, 1%*
R18	*1-Megohm*
S1,S2	*Miniature slide switch*
U1	*LM339N*
U2	*XRL556CP*
U3	*SN74HC04N*
U4	*LM 1403*
U5	*LM 330T-5.0*

supply). The logic thresholds themselves are set by a voltage divider network connected to an MC1403 precision voltage reference IC.[6] The MC1403 provides a stable temperature-compensated 2.5 volts output and operates at a supply voltage range of 4.5 to 40 volts. Because of this lower voltage limit, this device must be connected to V_{IN} and not V_{REG}, because the additional 0.6 volt drop would be too much. The resistor combination shown in **fig. 2** provides 0.8- and 2.4-volt references for the TTL window detector.

calibration and assembly

The only calibration required for this probe is to set the CMOS logic levels on the multi-turn pots. This is easily done by connecting the probe to a 10-volt supply and adjusting the pots until they provide 7 volts and 3 volts at pins 11 and 4, respectively, of the LM339.

I've tried to measure the maximum frequency and minimum pulse width this probe is capable of detecting, but the probe is capable of detecting higher speed pulses than my test equipment will provide. With my test equipment I've found that the probe will at least work up to 20 MHz (square wave input) and detect pulses as narrow as 20 nanoseconds. This is sufficient for most work currently being done, but still isn't the limit of the probe.

The slow response time of the comparators (LM339) results in the green and red LEDs turning on and a

flashing pulse LED for square wave inputs under about 2 MHz. For square waves over about 5 MHz, however, the green and red LEDs will be off (because of the slow comparators), but the pulse LED will still flash. Although I initially thought this was a shortcoming, others have suggested that this is actually useful because it provides a rough indication of speed. The probe will indicate a true pulse and logic level condition for all narrow pulses because one logic level is present for most of the time.

The pc board, which measures approximately 1 x 4 inches, fits nicely into a logic probe case available from Global Specialties.* The case comes with a probe tip and power cord, but the holes for the switches have to be drilled and a label made (if desired). The prototype used sockets for all ICs; this causes some height problems, however, and I recommend leaving them out.

The pc board artwork is reproduced in **fig. 3A**. **Figure 3B** illustrates the reverse side (component side) hole diagram as well as a computer-generated jumper placement. Point-to-point wiring is recommended for this side. **Figure 3C** details component placement using the same pattern shown in **fig. 3A**.

references

1. LM3301 5 0 data sheet, National Semiconductors
2. J. Rozenthal, "Improved Logic Probe," *ham radio*, April, 1983, page 91
3. SN74HC04N data sheet, Motorola
4. XRL556CP data sheet, EXAR.
5. LM339N data sheet, National Semiconductors
6. LM1403 data sheet, Motorola.

*Global Specialities, Inc., 70 Fulton Terrace; P.O. Box 1942, New Haven, Connecticut 06509.

ham radio

modifying microphones

Adapt yesterday's microphones for use with modern rigs

Although modern transceivers are designed to accommodate low-Z, hand-held microphones, some of us prefer desk-type units to handhelds. We'd like to use a prized older microphone but know it just won't match the new transceiver. Older microphones *can* be modified, however; this article describes some simple modifications and a special preamplifier that may be added if necessary.

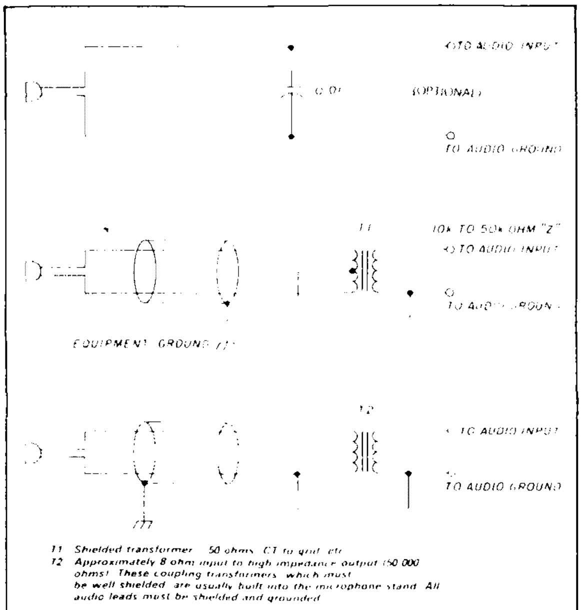


fig. 1. (A), Crystal microphone, approximately 50,000-ohm "Z"; (B), dynamic microphone, 50 ohms, Western Electric 600 broadcast types, etc.; (C), dynamic microphone, 8-500 ohms, into 10,000 to 50,000 ohm "Z."

Most modern rigs use low-Z impedance microphones, usually around 500 ohms. Because you can run a lower-Z unit into a higher Z-input and lose only gain, it isn't necessary to "match" the impedance, provided you have adequate microphone gain. No changes are necessary unless you want to use, for example, a Western Electric 50-ohm broadcast microphone with a 430S. In this sort of arrangement, it would be necessary to use a matching step-up transformer as shown in **fig. 1**.

Other low-Z microphones may also be used in this manner. Some manufacturers enclose the transformer and the 50-kilohm microphone in the same unit. Under these circumstances, the transformer must be magnetically shielded and preferably located in the base of the microphone stand. I found this system satisfactory for rigs that have adequate microphone gain; others may require an additional outboard preamplifier. Some manufacturers provide such units. As a rule, though, lower-output microphones are a better choice.

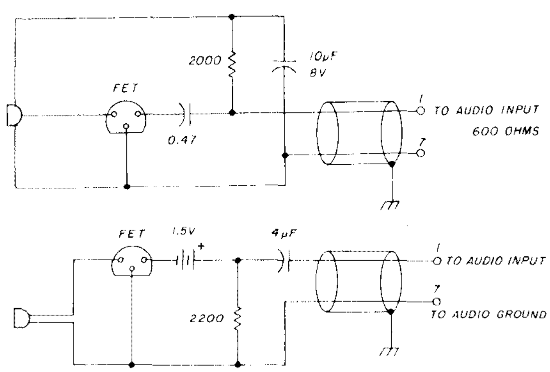
Crystal microphones can be used only into a high impedance input of 50 kilohms or more. An Astatic D104, for example, may be shunted at the microphone terminals with a $0.01\mu F$ capacitor to equalize the audio output.

Condenser Electret microphones (CEM), widely used by ICOM and other manufacturers, usually employ a transistor preamplifier built into the microphone capsule. This requires that preamplifier power be supplied. Generally a small battery is incorporated into the base of the stand, or, as in the Radio Shack 33-1058 tie clip that I use, a built in mercury cell is incorporated within the microphone case. No on/off switch is required because the life of the battery is equal to its shelf life. The IC-HM12, for example, obtains its preamp voltage from the transmitter (eg., IC 735, 745, 751), via the same terminal (No. 1) that carries the audio from the preamp. (See **figs 2 and 3**.)

The output impedance of these units is 600 ohms, at a level above that of an unamplified dynamic micro

By A.G. Sheffield, VE7CB/W6, Tri-Palms Estates, 32-291 Merion Drive, Thousand Palms, California 92276

phone. It should be noted that equipment designed for CEM microphone inputs will not have sufficient gain unless a preamplifier is added. Using the RS 33-1058 capsule, the circuit shown in **fig. 3** is more than adequate.



These units have 600 ohm output Z, use an amplifier built into the microphone capsule, and must have a battery supply included. All audio leads must be shielded, with the shield grounded to the chassis ground. The push to talk switch must also use the equipment ground.

fig. 2. Condenser Electret microphones employing built-in preamplifier circuits.

providing more gain

The preamplifier was constructed on a 1 X 2-inch piece of insulating board, with holes punched through for each component lead. It was wired directly into the microphone output and transceiver input via the microphone cord, directly from the base of the desk unit. (Note that the preamp termination must match your rig's input Z. Also, if a common audio and voltage line isn't used — as in the ICOM series — a battery for the preamp will be necessary.) Matching to 600 ohms is enhanced by using a larger transistor than normal and operating it at a lower level. I have used a 2N3053, 2N1304, 2N2430 satisfactorily in this application, with no hiss or distortion noticeable at full gain. It's very important that the audio line to the microphone plug be an insulated shielded wire and that the microphone and preamp ground be kept insulated and separate from the chassis ground. Pin 1 is audio, pin 8 is equipment ground, and pin 7 is audio ground.

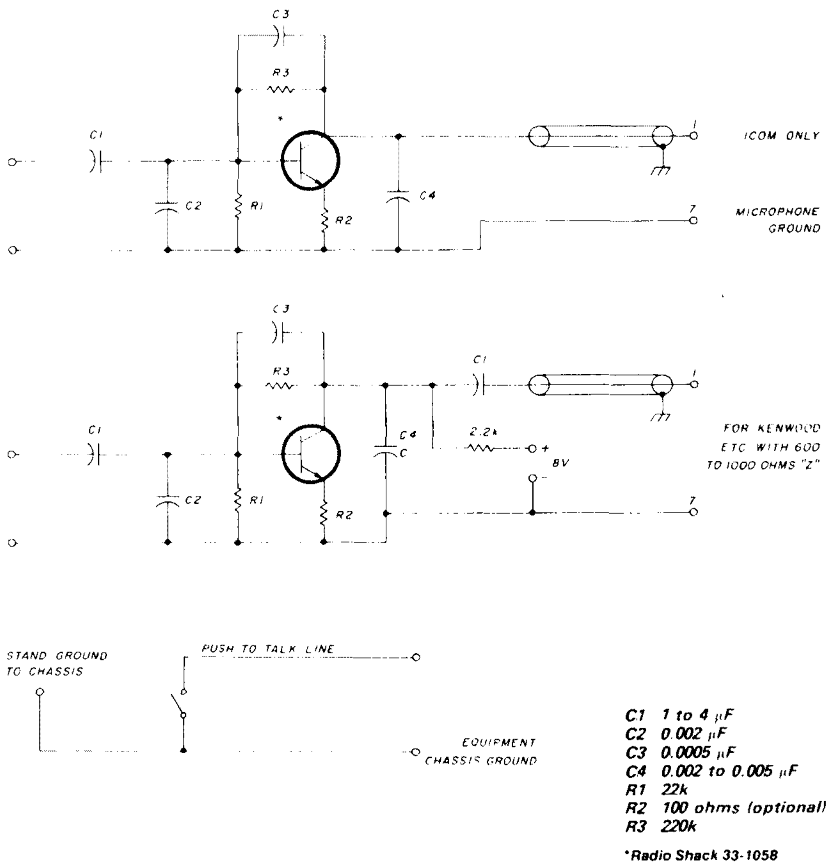


fig. 3. Microphone preamplifier circuits that can be used with ICOM and Kenwood transceivers.

This grounding method is essential in order to prevent hum and RF feedback. I wrap the microphone capsule with clear plastic tape to insulate it from the stand clamp. There should be no continuity path between the capsule and microphone stand; if there is, severe RF feedback will be evident.

For operation on SSB, it's especially important that the frequency response from 300 to 3000 Hz be flat and free of spurious peaks. Speech limiters and processing will level off these peaks somewhat, but it's at this point that the distortion inherent in such designs becomes apparent. Clipping produces square waves and harmonics within the audio range and is therefore not desirable. Response can be tailored to suit by reducing C1 for less bass and increasing the value of C2 for less highs. If full gain is required, remove emitter resistor R3. In my case, with the 745, the microphone gain is equal to the HM12's with the resistor left in. It is higher, but still within usable limits with the resitor out.

This low-cost, conventional design is the result of many hours testing different microphones and preamplifiers. Through its use, increased operating comfort — plus good voice quality and clean audio, with no spurs or splatter — can be achieved.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

"function generator" circuits: part 2

Last month we discussed using textbook integrator circuits as low-pass filters, for generating quadrature sine wave signals, and for generating triangle waves out of square waves. This month, we'll look at some practical circuits, keeping in mind that there's a serious difference between textbook circuits and real, on-the-workbench ones.

a practical integrator

Almost all textbooks on linear integrated circuits or operational amplifiers include the circuit shown in **fig. 1**. This circuit produces an output voltage that is related to the integral of the input signal and the gain ($-1/R1C1$).

The nature of the integrator is that it produces an output voltage that is the time-average of the input voltage. There's only one problem with the traditional circuit: with real operational amplifiers, it often doesn't work! But unfortunately, some articles and books don't tell you what the problem is and how to deal with it. When I first started building integrators several years ago I discovered the problem the hard way.

The main problem in practical integrators is that the dc offset voltage normally present at the output of real operational amplifiers charges capacitor C1, and thereby soon saturates the op-amp. The output voltage starts rising immediately after power is applied and soon is off scale.

One method used to cancel the effects of offset is to use an operational amplifier that has a very low offset potential and no input bias current (or very little). For low-cost applications, the CA-3140 BiMOS op-amp (which uses MOSFET input transistors) is a good choice. Devices of the 741 family are almost useless for integrator service except for periodic signals with no dc offset.

Another procedure is to connect a resistor across the integrator capacitor in order to keep the dc from building up (**fig. 2**). This is especially useful for integrators that see periodic input signals. The rule of thumb is to make the shunt resistor (R2) very much larger than R1. In the test case, I used a 470-k input resistor and a 10-Megohm shunt resistor, which worked quite nicely.

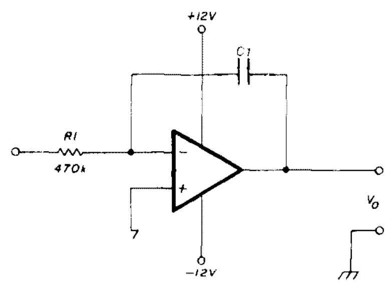


fig. 1. Basic integrator circuit uses op amp and single resistor/capacitor combination.

Finally, we may also have to use an offset null potentiometer in some circuits. In my test case, with 400-Hz sine, square, and triangle wave input signals, the potentiometer was not needed. Other cases, however, may require a counter offset provided by R3. Although the values of the resistors in this network are dependent upon the application, most of the time a 5-k value for R3, and 10 to 27-k for R4 and R5 will suffice. Make R6 equal to R1 for starters; it can be increased or decreased as needed after the circuit is tested.

To adjust the potentiometer, short the input of the integrator (making $V_{in} = 0$). Adjust R3 for a potential of zero volts at point "A." Momentarily close S1 to force the output voltage to zero. If the output voltage rises to either positive or negative values after S1 is opened, adjust R3 to cause the rate of increase to slow down to zero. Again close S1 and see if the output voltage changes. Repeat the procedure until the output voltage remains at zero following every closing of S1.

In normal operation, switch S1 is used to reset the integrator after it performs an operation. It is used in some instruments where a value is calculated, but is only occasionally needed in cases where an integrator sees a periodic signal with no dc offset component. For slow circuits, the switch can be a relay, while in faster circuits it can be a CMOS electronic switch with an "on" channel resistance very much lower than R1. Keep in mind that this switch dumps the charge in capacitor C1, so the CMOS switch selected must be able to withstand the charge in the capacitor without burning up.

sawtooth generator circuit

Not long ago, when I was building Science Workshop's "Poor Man's Spectrum Analyzer," decribed by W4UCH in a recent *ham radio* article,[1] I needed a sawtooth generator circuit from an oscilloscope. But W4UCH had used a 30-year old Heathkit, and modern oscilloscopes don't have a sawtooth output. (Mine is a modern triggered sweep model with "X-Y" capability.) *Although I eventually*

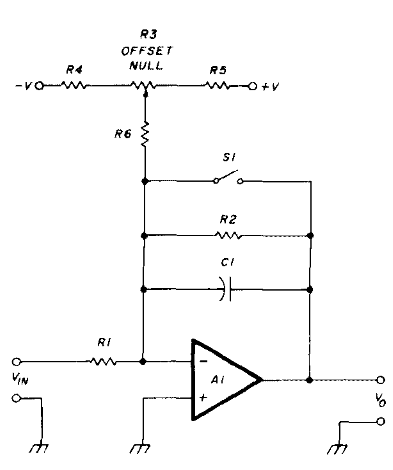


fig. 2. Use of resistor R2, in parallel with C1 prevents input offset voltages from saturating the op-amp.

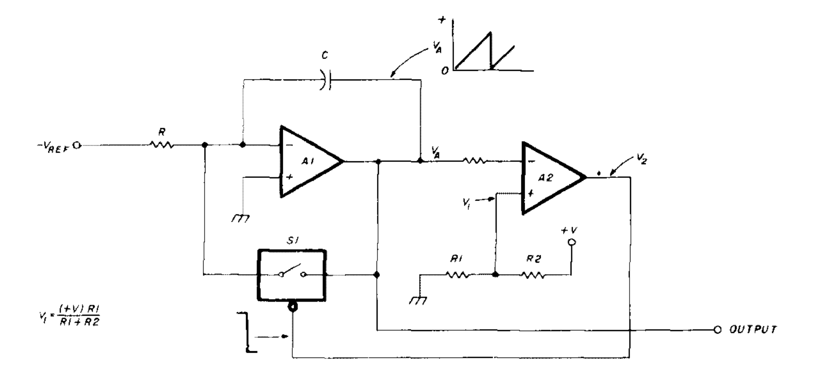


fig. 3. Integrator and comparator combine to form sawtooth generator.

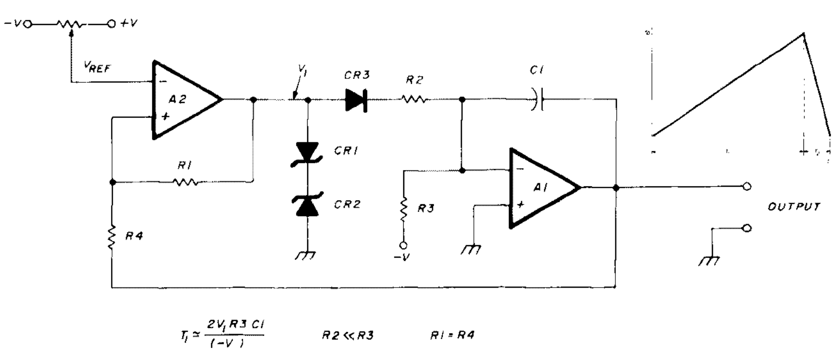


fig. 4. Sawtooth generator's decay time is function of R2/R3 ratio.

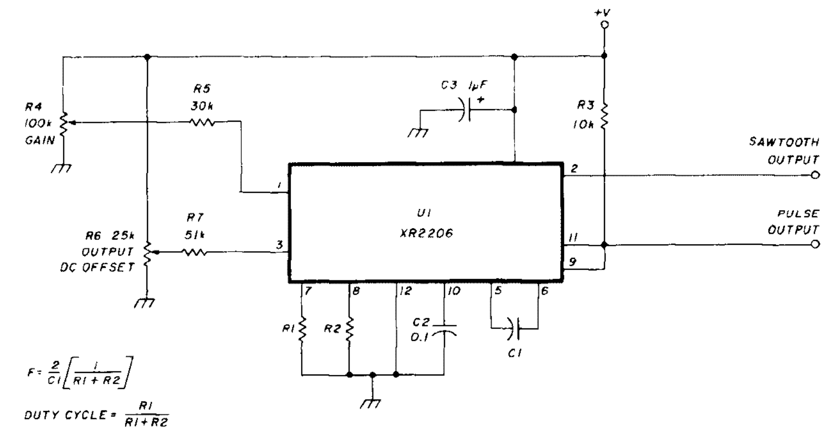


fig. 5. Circuit built around XR-2206 chip provides sawtooth and short pulse waveforms.

bought the Science Workshop sweep board described in W4UCH's article, I decided to look into sawtooth generator circuits. Because they're based on the integrator circuit, I decided to include them here.

Figure 3 shows one attempt at designing a sawtooth circuit. It consists of an integrator (A1) followed by a voltage comparator; the output of the comparator drives the control input on an electronic switch (which is active-LOW). At turn-on, the charge in capacitor C is zero, so voltage V_A is zero. Because voltage V1 is positive, the output of the comparator (V2) is positive. Under this circumstance the control line of S1 is inactive, so S1 is open.

At turn-on, the stable reference voltage $-V_{REF}$ causes the output of the integrator to increase. At the point where $V_A = V1$, the output of A2 drops LOW, forcing S1 to close. This discharges C, forcing the output voltage V_A down to zero.

Figure 4 was derived from a circuit given in one of Graeme's classic op-amp books.[2] The ramp generator circuit is the integrator formed with A1, C1, and R3 (being driven by V−). The output voltage rises until it reaches the threshold of comparator A2. That comparator uses positive feedback and a reference voltage V_{REF} provided by a potentiometer. The trip threshold is V_{REF} + V1 (which is set to 0.7 volts greater than the zener voltage of CR1/CR2, assuming that these diodes are identical). When the output voltage hits the threshold voltage, the comparator output snaps positive and forward biases diode CR3. If resistor R2 is very much less than R3, then C1 will discharge very rapidly, resulting in the classical sawtooth waveshape (see **fig. 4** inset). The reset time, T2, will

be very much shorter than the period, T1, if R2 < < R3.

Another means of generating a sawtooth waveform is to use a special function generator chip such as the Exar XR-2206.* The XR-2206 is capable of generating sine/square wave/ triangle waveforms; it is used to generate a sawtooth and a short duty cycle pulse in the circuit in **fig. 5**.

The frequency of this sawtooth generator circuit is set by resistors R1 and R2, plus capacitor C2:

$$F = \frac{2}{C1(R1 + R2)}$$

where: F is in Hz, C1 is in Farads, and R1 and R2 are in ohms. The duty cycle is:

$$\frac{R1}{R1 + R2}$$

Jameco** makes a circuit board "function generator" kit for less than $20 that creates the sine wave, square wave, and triangle wave signals. It can be easily modified for sawtooth applications.

references

1. Bob Richardson, W4UCH, "A Low-Cost Spectrum Analyzer with Kilobuck Features," *ham radio*, September, 1986, page 82.
2. Jerald G. Graeme, "Designing With Operational Amplifiers: Applications Alternatives," McGraw-Hill Book Company, New York, 1977, pages 159 162.

*Dick Smith Electronics, P.O. Box 8012, Redwood City, CA 94063-8021. Order part No. Z6820 ($3.95).
**Jameco Electronics, 1355 Shoreway Road, Belmont, CA 94002.

ham radio

open-wire line
for 2 meters

Low-loss, inexpensive VHF "cable"

It's a well-known fact that transmission line losses increase with the frequency of operation. Coax and open-wire line manufacturers supply data to permit users to select the proper transmission line for a given frequency. The data is usually in the form of dB loss per 100 feet, specified at discrete frequencies or by means of a curve expressed in dB loss per 100 feet versus frequency. Typical transmission line attenuation losses are shown in **table 1**.

line loss and cost considerations

For any frequency, it's possible to find a line that provides the lowest losses to the antenna system. For frequencies below 30 MHz, losses are not a problem unless line lengths are great — for example, over 300 feet at 30 MHz. At that frequency, RG8/U may produce a 3-dB loss over the line length, which represents one-half the power being lost in the coax line.

There's also a relationship between transmission line loss and cost, which is nonlinear. For a given frequency, cost versus line loss is an inverse function; that is, the lower the loss, the higher the cost. At 145 MHz, we have the choice of several readily-available transmission lines (**table 1**). The table also shows the market cost of each type as determined from recent magazine advertisements. Some of the transmission line costs are high, especially for long runs.

I'm interested in both minimum line loss and minimum costs. Reference 1 describes such lines for operation below 30 MHz in lengths of approximately 500 feet. Those lines are open four-wire transmission lines of 200 ohms impedance, which can be converted to 50 ohms with 4:1 baluns at the high frequencies. Open two-wire lines of 200 ohms impedance become impractical because of the very close spacing (less than 0.1 inch) required.

running the line

When it came time to consider the location of a 2-meter beam to pick up the Carolina DX Association repeater at a distance of approximately 50 miles, the closest tower was an 80-footer 120 feet from the operating position.

It has been my practice to bury coax cable from the house to the base of the antenna tower and run the coax up the tower. That practice was appropriate for low-frequency antennas in lengths of less than 200 feet. An alternative method would be to run a support line of steel cable between the house and the tower, securing the coax to the support line. Either way is acceptable; it's simply a matter of esthetics.

choosing the line

To run the coax underground and up the tower to the 50-foot level would require approximately 190 feet of transmission line. A suitable transmission line to produce an attenuation less than 2 dB for the total length would be one of the hard-line types.

Because of my successful experience with the four-

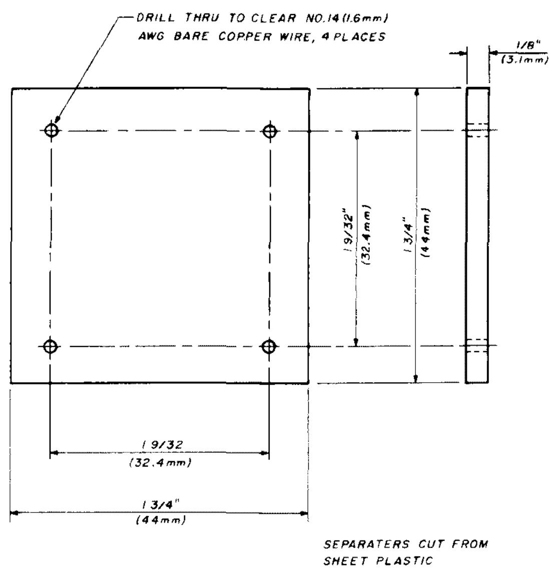


fig. 1. Dimensions of plastic spreaders for four-wire, 200-ohm transmission line.

By Henry G. Elwell, Jr., N4UH, Rt. 2, Box 20G, Cleveland, North Carolina 27013

Table 1. Attenuation as a function of transmission line length.

Cable Type	Impedance (ohms)	dB/100 ft (150 MHz)	Avg cost/100 ft (dollars)
RG213/U	50	2.3	30.00
RG8X	52	3.5	15.00
RG58/U	52	6.0	12.00
Aluminum (1/2 inch)	50	1.2	79.00
Heliax, (1/2 inch)	50	0.9	179.00
Heliax, (7/8-inch)	50	0.5	399.00
Four-conductor, open-wire	200	0.6	46.00

Notes:
1. Coax-type cables do not include connector cost.
2. The cost of the four-conductor open-wire line includes $36.00 for 400 feet of No. 14 copper wire plus an additional $10.00 for homemade spreaders and baluns.
3. The loss for the 200-ohm line is calculated from **eq 5** of reference 1.

wire, 200-ohm transmission line, I decided to use it for the straight-line, 120-foot run to the 2-meter antenna. Since I wanted as short a run as possible, the transmission line would be supported at the ends with no intervening support poles. That decision meant that the line would require good separation along its length as well as proper end supports.

building the line

Four 120-foot lengths of No. 14 copper wire were measured, and about a dozen square plastic spreaders made by W2IRC (**fig. 1**) were slipped on one end. That end was tied to a tree. The remaining spreaders were slipped on the other end, and the line pulled tight and secured. The spreaders were finally separated by a distance of 3 feet, with each hole encapsulated with silicone rubber to retain each spreader at its selected location. The transmission line was left undisturbed; after a few days, I found they were properly secured.

I used a special four-wire, 200-ohm terminating block, available from W2ER,* at each end. One was attached to the house and the other to the tower. Meanwhile, because commercial baluns for 145 MHz appeared to be unavailable, I made two 4:1 baluns. I decided small cores would be adequate for the amount of power to be used (25 watts maximum), so I wound Amidon iron-core type T94-12 cores as shown in **fig. 2** and soldered them to the cross-connected four-wire line at each end. Then I mounted a coax receptacle on the tower terminating block for ease of

*Marshall Etter, W2ER, 16 Fairlane Drive, East Quoque, New York 11942.

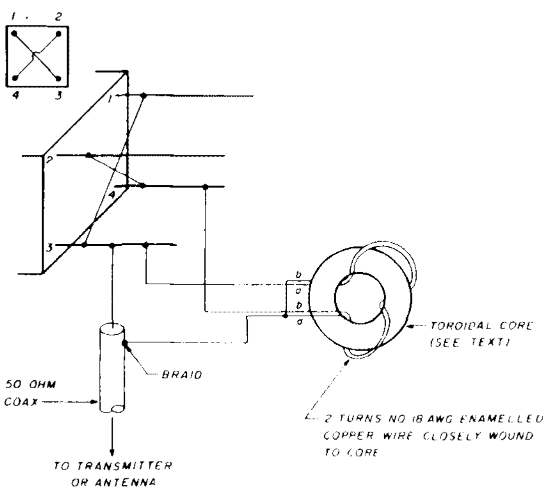


fig. 2. Connections of 50-ohm coax and 4:1 balun to four-wire 200-ohm transmission line, cross connected.

assembly and wrapped the baluns in tape for minimal weather protection.

final assembly

I connected one end of the transmission line under the eaves, then ran the line to the transmitter using a 15-foot piece of RG8/U coax. I connected the other end to the 80-foot tower at the 50-foot level, then added a noninductive, 50-ohm resistor across the coax connector at the tower. The VSWR of the line measured 1:1.

This whole exercise came about because of the prodding of N4ZC, who wanted me to be able to access the Carolina DX Association repeater located near the North Carolina/South Carolina border. His final exhortation included an offer to install the 10-element beam for me. With that kind of an offer, who could refuse?

N4ZC installed the beam at the 50-foot level, connected the 6-foot length of coax, and inquired whether the Carolina DX repeater could be accessed from the height. I raced into the house, raised the repeater, then ran outdoors again to report success!

Before this system was installed, I couldn't hear any signals at all from the Carolina DX Association repeater; now, operation over the less-than-ideal 50-mile path is satisfactory. And although the VSWR on the antenna system becomes very high during heavy rain storms, operation into other North Carolina repeaters has improved tremendously.

references

1. Henry G. Elwell, Jr., N4UH, "Long Transmission Lines for Optimum Antenna Location," *ham radio*, October 1980.

ham radio

the weekender

the weekender: aural VCO provides relative metering

Being an avid 2-meter foxhunter, I'm always willing to try out any new gadget that might serve that end. This article describes a circuit, shared with me by Don Lêwis, KF6GQ, for an RF sniffer which produces a tone that rises in frequency as the signal gets stronger. Ideas for a number of useful Amateur applications will be discussed.

how it works

Figure 1 shows the schematic for the aural VCO. The heart of the circuit is a 555 timer used as an RC audio oscillator. The frequency is determined by the RC values; increasing the value of resistance or capacitance lowers the frequency, while decreasing either has the opposite effect. In an HF VCO design, a varicap diode would be used as the variable element controlling the frequency of oscillation; at audible frequencies, however, conventional varicap diodes aren't effective. Instead, transistor Q5 and the 1000-ohm resistor form the variable element needed for controlling the frequency of our VCO by limiting the charging current flowing into the 0.15 µF timing capacitor according to the forward bias being applied to Q5.

As the voltage on pins 2 and 6 of U1 reach 2/3 Vcc (about 6 volts with a 9-volt supply) the timer will fire and pin 3 will be pulled low. Pin 7, an open collector output, goes low and begins to discharge the timing capacitor — through the 3.3-kilohm resistor. The discharge time provided by this resistor assures a reasonable, although asymmetrical, waveform for the aural signal generated by U1. At 1/3 Vcc the internal flip-flop resets, the output on pin 3 goes high, the open collector output on pin 7 floats, and the timing cycle begins again.

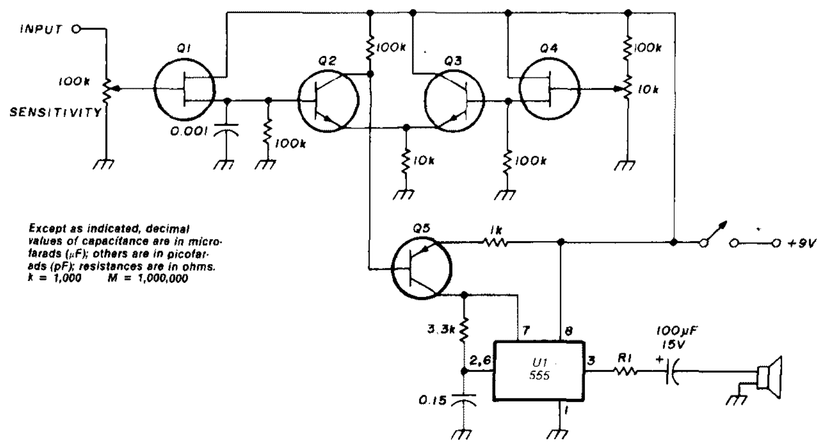


fig. 1. Aural VCO schematic parts values not shown are discussed in the text.

Transistor Q5, a PNP device, is used in a common collector configuration. Forward bias occurs as the base is driven towards ground. Transistors Q1 and Q4 form a differential amplifier. The quiescent bias for Q5 is set by the 10-kilohm pot's setting the bias at one of the differential amp inputs. The input signal, applied to the remaining differential amp input, in turn controls the forward bias of Q5. As the input voltage rises, transistor Q5 is driven further into conduction, reducing the RC time constant and thus increasing the frequency of the tone.

adjusting and using the VCO

The tone level is set through the value of R1, the resistor in series with the pin 3 output of U1 and the speaker. Battery life will be greatly reduced if too small a resistor is used for R1. Depending on the audio level

By Peter J. Bertini, K1ZJH, 20 Patsun Road, Somers, Connecticut 06071

needed, 47 to 1000 ohms will serve here. The 555 can source or sink upwards of 200 mA and will easily drive speakers with 8 to 45 ohms impedance. With no input signal the zero-set pot is adjusted for the desired resting tone. A steady click-click-click (similar to the sound of a Geiger counter) marks the lowest frequency that should be set. At this point any signal applied to Q1 will proportionally increase the tone frequency.

construction

Because layout is not critical, perfboard with 0.1-inch centers may be used for component mounting; all of the parts are available "off-the-shelf" from your nearest electronics distributor or Radio Shack. A 2N2222, 2N3904, or similar small-signal NPN device may be used for Q2 and Q3. A 2N2907, 2N3906, or similar small-signal PNP transistor will serve for Q5. Q1 and Q4 are N-channel JFETs; an MPF102, 2N5485, 2N5486, or 2N5487 will work well, although the pinch-off voltage rating, if too low, may limit the range of the device. Feel free to use junkbox parts if they're available; the circuit is forgiving of part substitutions.

putting the VCO to work

Figure 2 shows the VCO being used as a sensitive 2-meter field strength meter. Combined with a hand-held DF antenna, the meter lets you leave your vehicle and find a hidden transmitter within easy walking distance.

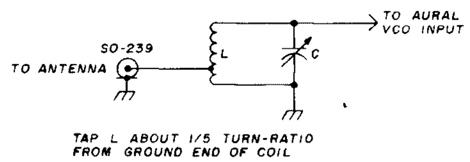


fig. 2. Using the aural VCO as an indicating device for a field-strength meter. The values for L and C should resonate at the frequency desired.

In a recent article I showed a simple external metering and attenuator for 2-meter FM transceivers.[1] Connecting this aural VCO to the signal-strength metering circuits allows you to orient your directional antenna without having to watch the S-meter — certainly a feature conducive to safe driving. Sightless or mobile HF operators might find that the aural VCO could replace the meter movement used for SWR bridges or relative output indication to facilitate antenna tuner or radio tuneup.

reference

1. Peter J. Bertini, K1ZJH, "The Foxbox: A Direction-Finding Tool," *ham radio*, October, 1985, page 25.

ham radio

an IF sweep generator

Versatile unit tests and aligns LC, crystal and mechanical filters

How would you like to have a versatile piece of test gear that could be used to align LC, crystal, or mechanical filters as well as to provide fm discriminator alignment? The generator described in this article can be set to a center frequency of 455 kHz and frequency modulated at any desired deviation up to ± 40 kHz. The sweep rate of 25 Hz is suitable for checking filters such as the Murata CFS series and for fm discriminator alignment. A 2-Hz rate is used for checking narrow-bandwidth crystal and mechanical filters. Linearity of sweep is excellent. A crystal diode detector is built in. A dc-coupled scope and a frequency counter are needed for calibration and display.

circuit operation

Referring to the schematic (**fig. 1**), U1, Q1, Q2 and associated components make up the rate and ramp generator. U1 is connected in the conventional astable circuit, but with the addition of CR4 and CR5 silicon diodes.

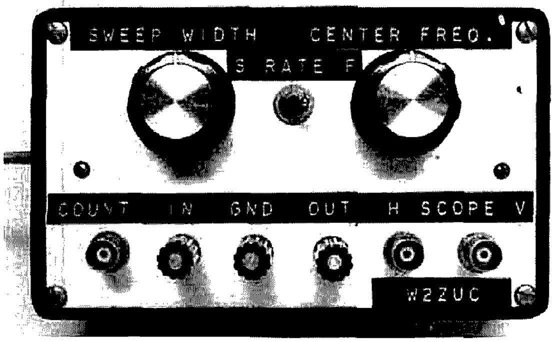


Photo 1. BP1 is labeled IN. Connect to input filter under test. BP3 is labeled OUT. Connect to output of filter under test.

Positive going pulses about 5 microseconds long occur at the output, pin 3, at 40-millisecond intervals (fast rate) and at about 480-millisecond intervals (slow rate).

Assume that at turn-on, C1 is at zero voltage. Q2 is turned off and C9 in the 555 timer circuit is also at zero voltage. C1 begins to charge through constant current generator Q1. A linear voltage ramp appears at Q2 collector. When U1 times out, a short positive pulse is coupled to Q2 base through R3. It turns Q2 on, which rapidly discharges C1, and the cycle is repeated at the rate selected by S1. Ramp voltage is applied to the gate of Q3, which is used as an inverting buffer and for dc-level shifting. Q3 drain is directly connected to modulation input pin 5 of U2, an LM566 function generator. It is a voltage-controlled oscillator, which outputs approximately square waves at pin 3 (not used here) and more or less triangular waves at pin 4. The changing voltage at pin 5 frequency modulates the output at pin 4, which is applied to the unit under test. Output from that unit is detected and filtered by CR3 and associated components, and a dc voltage proportional to this output is supplied to the scope vertical amplifier at J3.

The scope horizontal amplifier is connected to J1. The ramp voltage sweeps the trace left to right and the detected output voltage deflects the trace vertically. Thus the display can trace out the passband of a filter or the characteristic S-curve of an fm demodulator.

component selection

Capacitors C1 and C2 should be tantalum. C4 is polystyrene; an NPO ceramic would probably serve as well.

R1 in the constant-current generator limits charging current to C1, and its value may need to be changed to allow C1 to be charged to about 4 volts during the 40-millisecond period of the 25-Hz sweep rate. When in the 2-Hz mode, C1 will charge to about 8.5 volts. Neither value of voltage is critical.

Q2 must be a fast-switching type, capable of handling the high peak current that flows when C1 is discharged. Its duty cycle is very low. The 2N2222A used here has

By Bob Griffith, W2ZUC, 476 Keenan Avenue, Fort Myers, Florida 33907

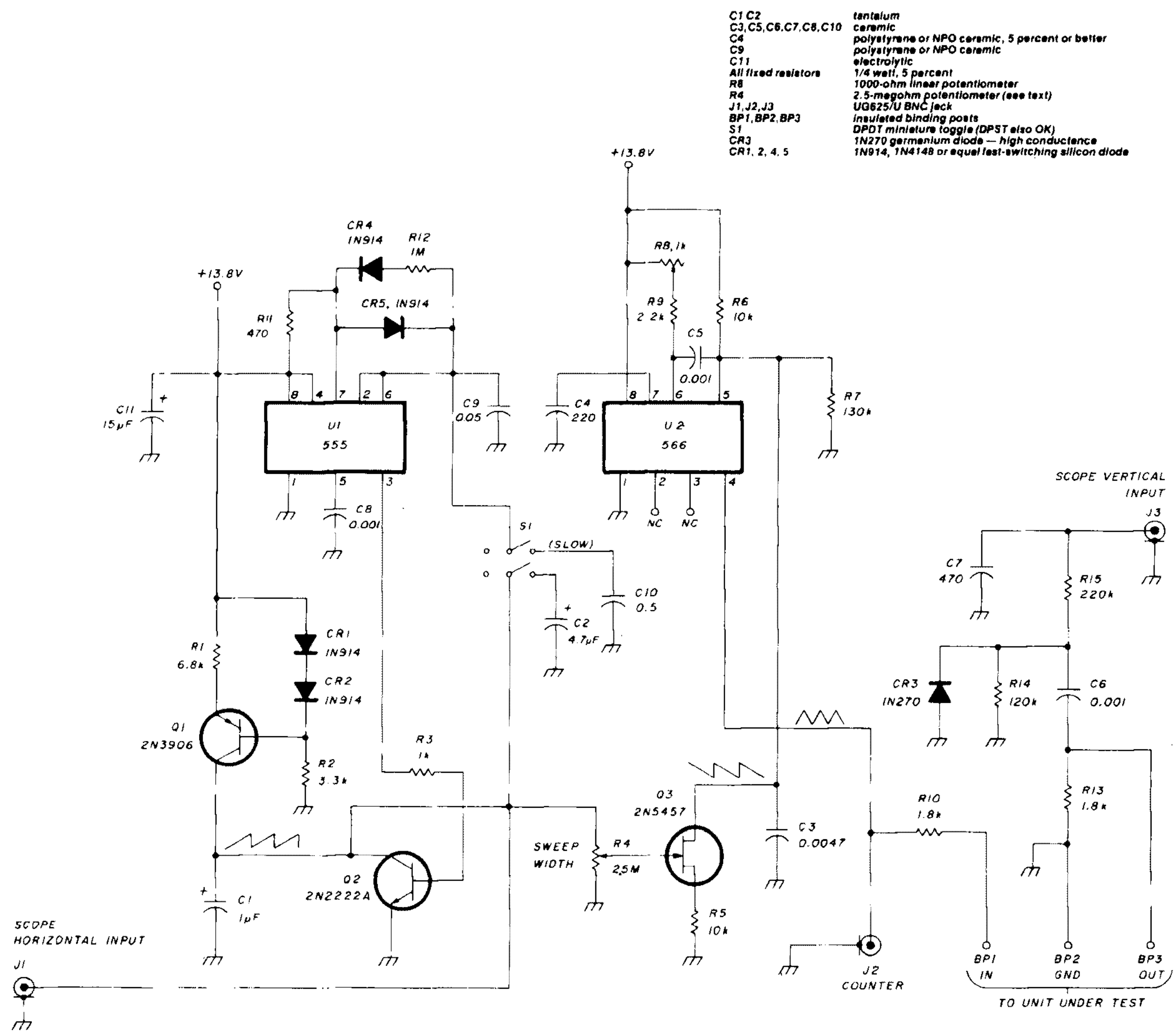


fig. 1. Schematic for the sweep generator.

survived many hours of operation. R3, the 1-kilohm resistor in series with Q2 base, is near the maximum value that allows the collector to be driven close to ground.

It's possible that U1 may fail to output the desired 5-microsecond pulse. If so, increase R11 to 1-kilohm, which will lengthen the pulse but won't upset operation.

Sweep width control R4 is a 2.5-megohm potentiometer. It may be replaced by a 1-megohm potentiometer in series with a 1-megohm fixed resistor to Q2 collector. The full ramp voltage isn't needed (or usable) at the gate of Q3.

Q3 is a readily available JFET. However, the spread in characteristics is broad, and it may be necessary to try more than one in this circuit. The selection can be made by setting up the test circuit of **fig. 2**. Pick a transistor that draws enough current to make the drain voltage approximately 12.0 volts and source voltage about 0.8

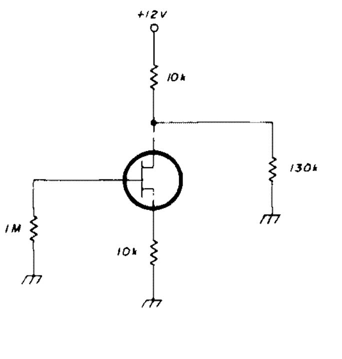


fig. 2. Circuit for testing the 2N5457 inverting buffer.

volts. The value of the 130-kilohm resistor can be varied ±20 percent if necessary.

U2 center frequency is determined by R8, R9, and C4. R9 is near the recommended 2-kilohm lower limit for the 566. When the sweep is zero, the output frequency can be varied from 350 kHz to 486 kHz. The upper frequency limit of the chip is 1 MHz, but any lower range can be obtained by increasing the values of R and C in the timing circuit.

The inverted ramp voltage supplied to U2, pin 5 from Q3 drain causes the VCO frequency change. Sensitivity is high; from a resting voltage of 12.0 volts, a drop of 0.1 volts to 11.9 volts increases the frequency about 22 kHz. Thus the output frequency at pin 4 increases during the ramp cycle, and the display is from left to right for increasing frequency.

Resting voltage at U2 pin 5 should be close to 12.0 volts for a 13.8-volt supply to obtain best linearity of sweep frequency. Total current drawn is 48 mA. An on-card 12-volt regulator can be used. If so, adjust the value of R7 to bias pin 5 at 10.5 volts. Closely regulated voltage isn't necessary, but it must be well filtered. The ramp generator and U2 are sensitive to hum voltages. For that reason, an external power supply is used.

construction

All the components except width control R4, center frequency control R8, S1 with C2 and C10, and the binding posts and jacks are on a single-sided board measuring 1.5 by 5 inches. I don't have a layout for it; I make lines and pads using dental burrs in a a high-speed grinder. Perf board should be acceptable.

The controls, switch, three binding posts, and three UG-625/U BNC jacks are mounted on an aluminum panel measuring 3.5 by 6 inches. The board is held to the panel by two small angle brackets. A short two-conductor cable with a two-contact male connector passes through a hole in the phenolic box, which measures 3.8 by 6.3 by 2 inches. No high frequencies are involved, but there are some high-impedance points and good insulation is needed.

initial checkout

Connect a counter to J2 and connect the scope DC vertical input to J1. Turn sweep width control R4 fully counter-clockwise and set center frequency control R8 fully clockwise. Set S1 to fast and apply well-filtered 13.8 volts to the power connector. The frequency should be about 486 kHz. Turn the center frequency control fully counter-clockwise. The frequency should be about 350 kHz. If the upper frequency is below about 475 kHz, you can shunt R9 with a fixed resistor from 22 kilohms upward, or try a slightly smaller value of capacitor at C4. The upper limit isn't critical, but it must be high enough to allow setting of the frequency at the upper point of a filter under test, which will be explained later.

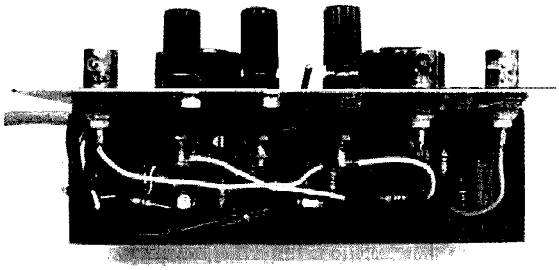


Photo 2. Bottom view of circuit board. The 555 timer is at left. Q2 and Q1 are next to the right. Q3 is near the front of the board between BP1 and BP2. The 566 is near the center of the board. Detector and associated components are at the right end.

Check the ramp voltage. It should be a very linear sawtooth having a period of approximately 40 milliseconds and a peak amplitude of about 4 volts. If no signal is here, check Q1 for short or open circuit and check Q2 base for a positive-going pulse. If it's missing, check the 555 timer. Set S1 to slow. The sawtooth amplitude should be about 8.5 volts and the period near 480 milliseconds.

This procedure assumes that you have a scope with a calibrated sweep. If not, the counter should work on the 25-Hz rate, and the 2-Hz rate can be estimated by visual check against a sweep second hand. Neither rate is really critical. If you don't intend to check very narrow filters, the slow rate and switch can be eliminated.

Disconnect the counter and connect the scope probe to J2. Turn the sweep width control to about 10 o'clock. Triangular waves about 3 volts peak-to-peak above a 5-volt DC level should appear. Successive waves should appear to move left and right at the repetition rate of the ramp voltage. If little or no movement can be seen, check for a signal at the gate of Q3 and at its drain. If there's a normal signal at the gate but no inverted signal at the drain, check the dc bias at the drain and at pin 5 of the 566.

Connect a jumper from BP1 to BP3 (binding posts). Connect the scope dc horizontal input to J1 and vertical input to J3. Turn the sweep width control to minimum. Vary the center frequency control through its range and observe the trace on the scope face. It should be a straight line at 400 to 500 millivolts above ground. Turn up the width control. Output at J3 should not change except near maximum sweep.

calibration and use

Connect the input of the filter to be tested to BP1, ground to BP2, and the output of the filter to BP3. Set the center frequency and width controls to obtain a display that looks like an inverted U. Check both sweep rates. If there's a noticeable difference in the trace shape, use the slower rate. Increase the sweep width and note

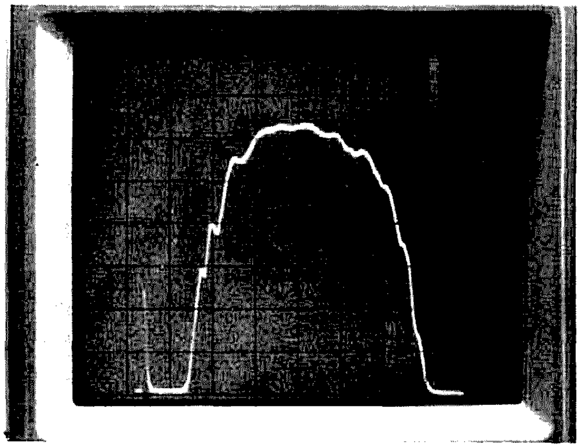


Photo 3. Scope display of passband of Murata CFS455E filter. Each horizontal division is 0.5 volts. Each vertical division is 50 mV. Sweep rate is 25 Hz. The 6dB points are at 446 and 466 kHz. The pip at left of trace is not a spurious response of the filter. It is display of retrace during the negative going portion of the ramp voltage, since there is no blanking during that interval.

that the trace moves to the left. This is normal. Restore to center by adjustment of the center frequency control.

Reconnect the counter to J2. Position the trace so that a point near the middle of the passband is at some easily noted height — for example, six divisions above the zero-volt baseline. Reduce the sweep to zero and adjust the center frequency control for six divisions in height of the now-straight horizontal line. Read the frequency from the counter. This is the frequency for approximately the center of the filter. Now readjust the center frequency control for three divisions in height at both low and high-frequency ends of the passband. Read the counter again. These frequencies are at the 6-dB points for that filter. Symmetry and ripple within the passband are easily seen on the display.

It's impossible to determine the 60-dB points accurately on a filter passband using the simple diode detector in this unit. An idea of the skirt selectivity and presence of nearby spurs can be obtained by reducing scope attenuation to a minimum. Alternatively, you might disconnect the detector circuit and measure the output voltage of the filter with a well-calibrated RF millivoltmeter.

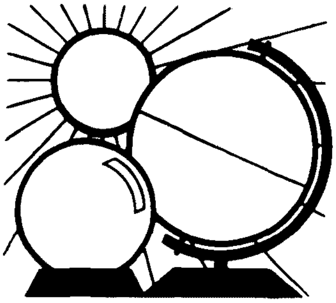
For narrow passband ceramic or crystal filters, follow the manufacturers' recommendations for input and output terminations. The values may be quite different from the 1.8 kilohm series and shunt resistors I chose. (Mine were close to the 1.5-to-2 kilohm terminations specified for the Murata CFS series filters that are commonly used in 2-meter fm receivers and in VHF marine radios.) Mechanical filters usually require shunt C at both input and output to resonate the coupling coils within them. You may wish to remove R13 from the board and use it or other values externally between BP2 and BP3.

For the home brewer of multipole crystal filters, this generator should make it much easier to trim to the desired center frequency and minimize ripple.

For discriminator alignment, input a signal through a capacitor of 1000 pF to a point in the receiver ahead of the discriminator but following any 455-kHz filter. Use a 1-kilohm potentiometer for level adjustment and check with a scope to see that sufficient signal is injected to cause limiting before the discriminator. Set the center frequency and sweep width as required to obtain a trace of the S-curve and adjust the primary and secondary for best linearity. The desired center frequency should be halfway between those at the ends. If a very narrow (for fm) filter such as the CFS-F is used in the receiver, you may wish to remove the filter and determine its actual passband and center the discriminator to match.

You can also determine the curve for the ceramic discriminator now used in many 2-meter transceivers. These are fixed and no adjustment is provided. They appear to be inferior to a good Foster-Seeley discriminator with respect to linearity, although they are undeniably smaller and probably less expensive.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

DX propagation

When you're working DX, you can usually expect that the conditions that optimize your transmitted signal will do the same for your receiving capability. There are exceptions to this rule, of course — during ionospheric tilt conditions, for example.*

For the strongest signals, it's best to use the highest frequency band (i.e., near the maximum usable frequency, or MUF) the ionosphere will support for the path in the direction of interest (see chart). Doing so reduces the number of hops required through the signal-absorbing D-region to the distant station and results in a stronger, more readable signal with less distortion and variation.

To be able to use the maximum hop length (the lowest number of hops) the take-off angle (TOA) of the signal from the antenna must be about 10 degrees. The longest paths in the chart are to Australia (from Eastern USA), South Africa (from mid-USA), and Antarctica (western USA). All of these paths' hop lengths are between 1711 and 2456 miles, with TOAs within a range of from 3 to 9 degrees and 2 to 5 hops.

Because the MUFs and TOAs exhibit diurnal, seasonal, and solar variations (sunspot/solar flux numbers), a new chart is published each month. MUFs for specific locations can be found by using programs like MINIMUF 3.5[1] and modified versions that consider other path parameters such as bearings, distances and TOA, as discussed in previous columns.[2,3]

*(We like to think of the D, E and F region as concentric layers, but this is not always the case—Ed.)

The italicized numbers in the chart refer to MUFs during the night and predawn hours, which may be problem times. At these times, particularly near sunrise, the ionosphere develops a tilt that causes rapid changes in frequency and height, affecting east-west paths every day. Bands come in or go out at these sunrise and sunset times on the path, and DX openings are often unusually good, if brief.

To be continued next month . . .

last-minute forecast

Because of the increased probability of solar activity, the middle of January is expected to be the best time for openings on 10 through 30 meters. Good transequatorial openings in the evenings can be expected to continue through the third week of the month, when an unstable geomagnetic field is anticipated. The lower frequency bands, open mainly during the night, should be at peak performance during the first week of the month. The last week will also be very good, except for a greater probability of lower-level signals being affected by winter anomolous absorption after the 15th.[4] However, because January is the month in which atmospheric noise is lowest and the geomagnetic field is least disturbed, operation should be *outstanding*.

band-by-band summary

Ten, twelve, fifteen, and twenty meters will be open to most areas of the world from morning to early evening almost every day. Openings on the higher of these bands will be shorter and will occur closer to local noon. Transequatorial propagation on these bands will more likely occur toward evening during conditions of highest solar flux and disturbed geomagnetic field conditions.

Thirty and forty meters will be useful almost 24 hours a day. Daytime conditions will resemble those on 20 meters. Skip distances and signal strength may decrease during midday on days that coincide with the higher solar flux values. Nightime DX will be good except after days of high MUF conditions and during geomagnetic disturbances. Look for DX from unusual places on east, north, and west paths during this time. The usable distance is expected to be somewhat less than 20 in daytime and greater than on 80 at night.

Eighty and one-sixty meters will exhibit short-skip propagation during daylight hours and lengthen for DX at dusk. These bands follow the darkness regions, opening to the east just before local sunset, swinging more to the south near midnight, and ending up in the Pacific areas during the hour or so before dawn. The 160-meter band opens later and closer earlier than 80.

references

1. Robert B. Rose, K6GKU, "A Simplified MUF-Prediction Program For Microcomputers," *QST*, December, 1982, page 36.
2. Garth Stonehocker, KORYW, "Antenna-to-Ionospheric Path Match," DX Forecaster, *ham radio*, October, 1986, page 92.
3. Garth Stonehocker, KORYW, "Ionosphere Matching," DX Forecaster, *ham radio*, January 1985, page 92.
4. Garth Stonehocker, KORYW, "More On Winter Anomalous Absorption," DX Forecaster, *ham radio*, December, 1986, page 101.

ham radio

JANUARY

WESTERN USA

GMT	PST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	4:00	_40_	40	20	12	12	10	12	20
0100	5:00	30	40	20	15	12	10	10	20
0200	6:00	30	_40_	20	20	12	12	12	20
0300	7:00	40	_40_	30*	20	15	15	15	30
0400	8:00	40	_40_	_30_	20	20	20	20	30
0500	9:00	40	_40_	_30_	20	20	20	20	40
0600	10:00	40	_40_	_30_	30*	20	20	20	40
0700	11:00	40	_40_	_30_	_30_	20	20	30	40
0800	12:00	40	_40_	_30_	_30_	20	_30_	30	40
0900	1:00	40	_40_	_30_	_30_	_30_*	_30_	_30_	40
1000	2:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
1100	3:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
1200	4:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
1300	5:00	_40_	_40_	20	20	_30_	_30_	_30_	_40_
1400	6:00	_40_	30	12	12	_30_	_30_	_30_	_40_
1500	7:00	_40_	20	12	12	20	20	_30_	_40_
1600	8:00	40	20	10	10	15	30	20	_40_
1700	9:00	40	20	10	10	15	20	20	_40_
1800	10:00	40	30	10	10	15	15	20	_40_
1900	11:00	_40_	40	10	10	12	15	20	_40_
2000	12:00	_40_	40	12	10	12	12	20*	30
2100	1:00	_40_	40	12	10	12	12*	15	20
2200	2:00	_40_	40	15	10	12	10	12	20
2300	3:00	_40_	40	20	10	12	10	12	20

MID USA

GMT	MST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN	CST
0000	5:00	_40_	40	20	15	12	10	12	20	6:00
0100	6:00	30	40	30	20	15	12	12	30	7:00
0200	7:00	30	_40_	30	20	15	15	12	30	8:00
0300	8:00	40	_40_	_30_	20	20	20	12	40	9:00
0400	9:00	40	_40_	_30_	20	20	20	15	40	10:00
0500	10:00	40	_40_	_30_	20	30	20	20	40	11:00
0600	11:00	40	_80_	_30_	_30_	30	20	20	40	12:00
0700	12:00	_40_	_80_	_30_	_30_	_30_	30	20	40	1:00
0800	1:00	_40_	_80_	_30_	_30_	_30_	_30_	_30_	40	2:00
0900	2:00	_40_	_80_	_30_	_30_	_30_	_30_	_30_	_40_	3:00
1000	3:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_	4:00
1100	4:00	_40_	_40_	20	_30_	_30_	_30_	_30_	_40_	5:00
1200	5:00	_40_	40	15	20	_30_	_30_	_30_	_40_	6:00
1300	6:00	40	30	12	15	_30_	_30_	_30_	_40_	7:00
1400	7:00	40	20	10	12	20	20	_30_	_40_	8:00
1500	8:00	40	20	10	12	20	20	20	40	9:00
1600	9:00	40	20	10	10	15	20	20	40	10:00
1700	10:00	40	20	10	10	15	20	20	_40_	11:00
1800	11:00	40	20	10	10	12	15	20	_40_	12:00
1900	12:00	_40_	30	10	10	12	15	20	_40_	1:00
2000	1:00	_40_	40	10	10	12	12	15	_40_	2:00
2100	2:00	_40_	40	12	10	12	12	15	30	3:00
2200	3:00	_40_	40	15	10	12	10	12	30	4:00
2300	4:00	_40_	40	15	12	12	10	12	20	5:00

EASTERN USA

GMT	EST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE CARIBBEAN S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	7:00	_40_	40	20	20	15	12	15	40
0100	8:00	_40_	40	30	20	20	20	20	40
0200	9:00	40	_40_	_30_	20	20	20	20	40
0300	10:00	40	_80_*	_30_	20	20	20	20	40
0400	11:00	40	_80_*	_30_	20	20	30	30	40
0500	12:00	_40_	_80_	_30_	_30_	20	30	30	40
0600	1:00	_40_	_80_	_30_	_30_	_30_*	_30_	_30_	40
0700	2:00	_40_	_80_	_30_	_30_	_30_	_30_	_30_	_40_
0800	3:00	_40_	_80_	_30_	_30_	_30_	_30_	_30_	_40_
0900	4:00	_40_	_80_	_30_	_30_	_30_	_30_	_30_	_40_
1000	5:00	_40_	40	20	_30_	_30_	_30_	_30_	_40_
1100	6:00	40	30	12	20	_30_	_30_	_30_	_40_
1200	7:00	30	20	10	15	_30_	_30_	_30_	_40_
1300	8:00	40	20	10	12	20	20	20*	40
1400	9:00	40	20	10	12	20	20	20	40
1500	10:00	40	20	10	12*	15	20	20	40
1600	11:00	40	20	10	10	15	20	20	_40_
1700	12:00	40	20	10	10	12	20	30	_40_
1800	1:00	40	20	10	10	12	15	20	_40_
1900	2:00	40	30	10	10	12	12	20	_40_
2000	3:00	_40_	40	12	10	12	12	15	_40_
2100	4:00	_40_	40	12	10	12	12	15	30
2200	5:00	_40_	40	20	12	12	10	12	20
2300	6:00	_40_	40	20	15	12	12	12	30

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

product

REVIEW

Heath SA-2550 remote antenna matcher

Heathkit has always been known for being the "haven" for gadgeteers — I'm one of them, and I've always been intrigued by their various offerings.

Their latest Ham gadget is the new Remote Antenna Matcher, the SA-2550 (see **fig. 1**). Simple in design but elegant in use, this remotely tuned 40-500 pF variable capacitor can be continuously varied from the comfort of your hamshack.

The control unit is a power supply and dc rectifier with a switch that allows you to turn the capacitor either clockwise or counter-clockwise by reversing the polarity of the voltage it sends to the matching unit motor. The motor-driven capacitor moves slowly enough so that it's hard to miss the lowest point of SWR, but not so slowly that you have to wait forever for it to make its rounds. The control voltage can be sent to the remote unit either through the antenna feedline or through two control wires.

Heath designed the Remote Matcher to be compatible with their Remote Antenna Switch (see the product review on page 124 of the May, 1986 issue). If you want to use the two units together, you'll have to control the remote matcher through the two external wires because of a dc-blocking capacitor in the HA-1481; in most Amateur installations, this will be no more than a minor inconvenience. Owners of other brands of remote switches will have to check their schematics to see what configuration their units use. If you use external cable to control your remote switch, you'll be able to use the feedline to control the SA-2550. If the remote switch uses the feedline for control, you'll need to use two external wires.

construction

Heath should get an award for their construction manuals. My hat's off to their technical writers. While this isn't a particularly difficult kit to build, the clear, concise style of writing makes building *very* easy.

As per any kit, I highly recommend you read the manual at least twice before you even open one parts envelope. Then, I suggest you take a complete parts inventory to make sure that nothing is missing. Try stealing a muffin pan from the kitchen and use it to sort and organize all the parts. This is especially helpful with all the hardware: screws, nuts, bolts, and washers. A few extra minutes in organization will save plenty of time later on.

Construction is straightforward and really progresses quite quickly. You start with the control unit/power supply (about an hour's work) and then move on to the matcher unit chassis. Here's where it gets a bit interesting; building the capacitor proved to be a slight stumbling block for me. It wasn't the instructions or anything other than my own sloppiness. Putting all the plates of the stator and rotor together went fine, but I had my problems in getting the proper alignment between the plates. I spent a little time carefully adjusting the four alignment nuts and had the capacitor positioned exactly where it was supposed to be. (If the plates aren't properly spaced and aligned, the voltage rating will decrease and the capacitance won't be within specifications. The unit won't perform as it should and could arc over under full-power applications.)

After the capacitor was set aside, completion of the project took just about an hour more. My total time into the project was about three hours, with another ten minutes to run some resistance and voltage checks and to run the operational "smoke" test. When it was all hooked up, everything worked as expected.

Though I was impressed with the motor that Heath supplies to turn the capacitor, I was a little concerned that I hadn't left enough slack in the capacitor's rotor and that the motor would have trouble turning the capacitor. Not to worry: my guess is that the motor could probably be used to turn the Empire State Building! There's plenty of torque, with some to spare. The motor gear drive lube is specified for operation over −40 to +60 degrees.

installation

The remote matcher is designed to be mounted at the antenna feedpoint. If you're designing a dipole, the remote matcher can be used in place of a center insulator. It's too heavy, however, to be used without support and should either be mounted on the side of a tower or suspended from a catenary wire.

Here's a typical installation you might use with the remote matcher. Cut an antenna to the middle of the 80-meter band. By formula, each leg of the dipole will be approximately 64.3 feet. (Heath recommends that you add an additional 15 percent — in this case, 9.6 feet — to the length of each leg.) Each leg of the dipole becomes 73.9 feet long. Installation proceeds as with any other dipole, except in that the remote matcher takes the place of the center insulator. When the antenna is installed, the capacitor is

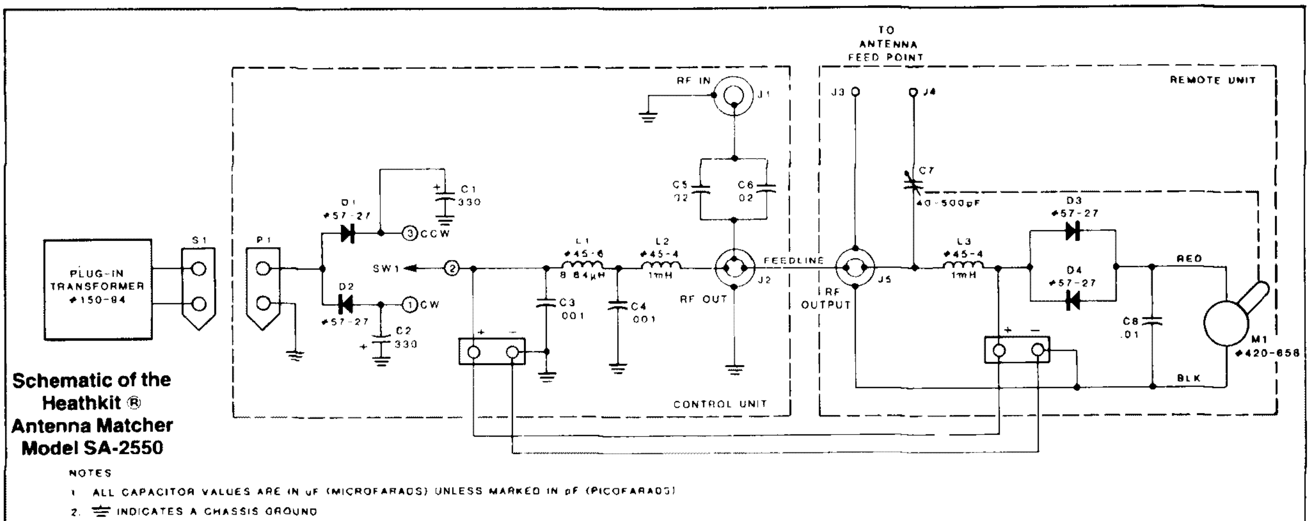


fig. 1. Heathkit antenna matcher (SA2550).

used to tune out the reactive inductance of one leg of the antenna as you move away from the design frequency. This allows the transmitter to see close to a 50-ohm impedance over a wider portion of the band. This "magic" is accomplished by varying the capacitor over its tuning range and adjusting for minimum SWR.

Heath includes instructions on using the remote matcher with inverted Vs and bottom fed verticals of both single and multi-band designs.

tuning and adjustment

Simply hook the remote unit up according to Heath's instructions and you're ready to go. If you have a linear amplifier, don't use it during tuning of *any* antenna; you could damage both the remote matcher and the amplifier.

Key the transmitter in CW on the bottom of the band you want to use and turn the remote capacitor until you have a minimum SWR reading. It's a good idea to tune up the whole band and make yourself an SWR chart to refer to so that you'll know approximately what SWR you're looking for as the antenna nears resonance.

Quoting from Heath's instruction manual: *when the antenna is properly tuned at the low end of the band, with the Antenna Matcher adjusted for minimum SWR, the Variable capacitor should be between 2/3 and 3/4 meshed. You do not want a situation where the capacitor is either fully closed or fully open. If the capacitor is fully closed when tuned for the low end of the band, the antenna is too long. On the other hand, if the capacitor is fully open at the high end of the band, the antenna is too short.*

other applications

With the addition of a tapped coil and relays, you can use the Remote Matcher as a multi-band tuner. Consider the application discussed by Jack Belrose, VE2CV, in a *ham radio* article ("The Half-Delta Loop") in May, 1982. In a follow-up article written with Doug DeMaw and published in *QST* (September, 1982), the idea was further pursued, with actual on-the-air testing. The antenna was fed with a remotely tuned LC network (with variable C and tapped L — see fig. 2). The problem in replicating this antenna was locating a suitable remotely tuned capacitor. The SA-2550 seems to be designed with this project in mind.

Using a tuning network with the same configuration, you can tune a variety of different antennas for full- and multi band performance. Folded uni-poles, base-fed verticals, Bob-tail Curtains, and loops of all kinds are just a few of the examples of antennas that can be used with this remotely controlled capacitor.

While not inexpensive ($149.95), the Heath SA-2550 represents a great value for anyone who's looking for a way of remotely tuning antennas. I had fun with this project and look forward to trying out all my antenna ideas before too much snow flies. See you on the bands!

Circle #301 on Reader Service Card.

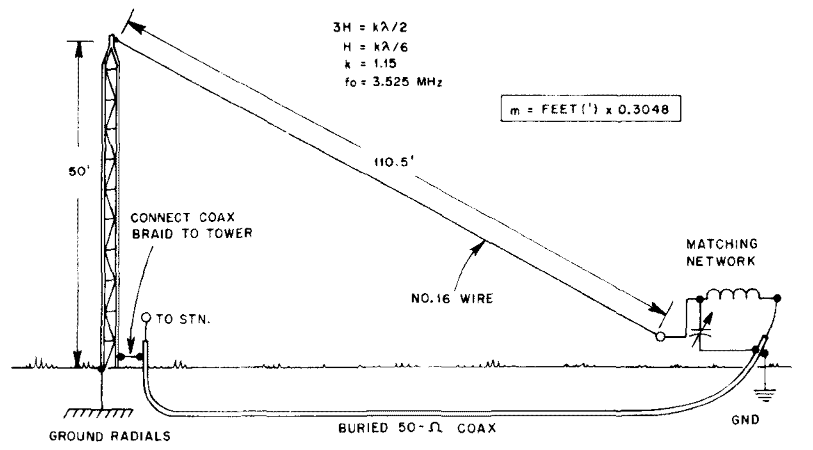


fig. 2A. The half-delta loop. (Reprinted with permission from QST, September, 1982, page 31.)

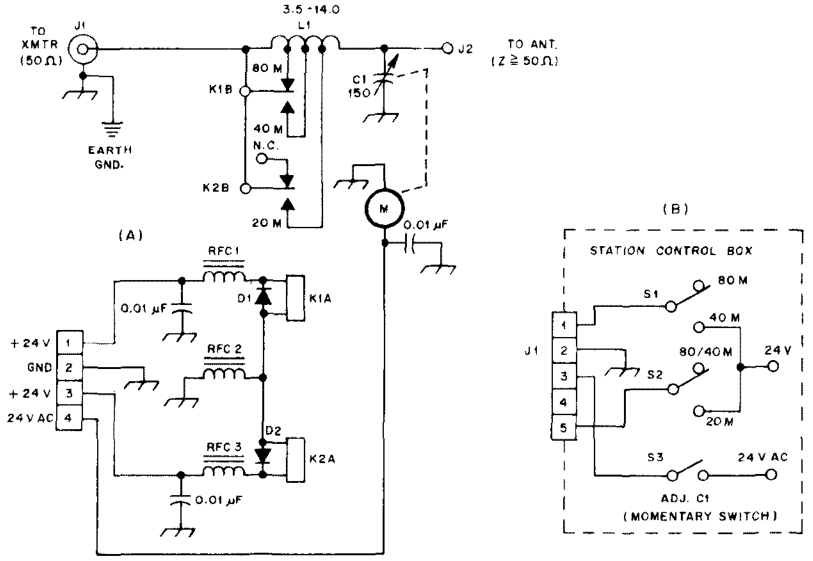


fig. 2B. Three-band L-network matches half-delta loop to 50-ohm cable. (Reprinted with permission from QST, September, 1982, page 31.)

NEW products

packet repeater controllers

Pac-Comm has announced the release of its new DR-series of packet repeater controllers. The DR-200 dual-port controller provides an inexpensive, off-the-shelf packet switch to move traffic on inter-LAN networks. The DR-100 provides basic, single-port controller capability in a ruggedized package at low cost, and is well suited to applications in which a single-frequency repeater is appropriate.

Both units share the same digital design, which provides a Z80 CPU with up to 32k bytes of EPROM program storage and up to 32k bytes of RAM for buffering, configuration parameters, and other functions. Packet HDLC operations are handled by a Z8530 Serial Communications Controller.

The DR-200 has two independent 300/1200 baud modems using the AMD 7910 World Chip™ modem. Each modem channel also has a standard disconnect header for accessory modems. Both channels have PTT line time-out-

NEW products

timers and the CPU has a watchdog timer. Both models support two methods for communication with external terminals.

Several versions of dual-port software adapted to the DR 200 are available through Pac Comm. The "Dual Port Digipeater" program written by Jon Bloom, KE3Z, uses an easily-implemented routing algorithm based on default SSID's and an explicit routing table. The single- or dual-port version of the "AX.25 Level 3 Packet Switch" program by Howie Goldstein, N2WX, is available for both the DR 100 and DR 200. The other single-port program is an adaptation of Pac Comm's Version 1.1.3 that provides standard AX.25 Level 2, Version 2 digipeater support. All software has been enhanced to utilize the optional serial ports for setting site-specific parameters. Any one of these programs may be selected with the purchase of a Pac Comm digital controller and will be provided at no charge; additional copies are available for the cost of reproduction and documentation.

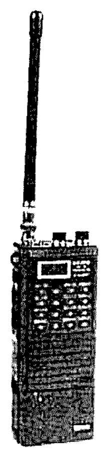
At presstime, the DR 100 Single-Port was priced at $79.95 (kit) and $99 (assembled). The DR 200 Dual-Port was priced at $139.95 (kit) and $159.95 (assembled); final prices may be subject to variation because of changes in the semiconductor market.

For complete details, contact Pac Comm Packet Radio Systems, Inc., 3652 West Cypress Street, Tampa, Florida 33607.

Circle #302 on Reader Service Card.

ICOM IC-03AT 220-MHz handheld

ICOM has announced the release of the IC-03AT, a new 220 MHz counterpart to its IC-02AT and IC-04AT top-of-the-line handhelds.



flea market

PACKET PROGRAM FOR YOUR PC. A telecommunications program especially written to interface your packet controller with your PC or compatible. Features Split Screens, ASCII, Binary, X-Modem file transfers, DOS shell, Macro Keys, 5 types time date/oper ID. Lots of goodies. Software support. Write for complete information. VISA/MC. Kail and Associates, 2440 E. Tudor Rd. Suite #138, Anchorage, AK 99507. (907) 248-0133

REMEMBER TROLLEY CARS? Trolley Treasures "The Wartime Years in New Jersey" (1939-1947), a 4-volume photo/documentary history, includes 1000 unpublished original photographs plus extensive historical notes. Volume 1 "The Compromise Roof Cars of Public Service Coordinated Transport" ready now. For details, or to order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. $17.95 plus $1.50 S&H.

WANTED: Tube Hi-Fi Equipment, loudspeakers, magazines. Anything relating to 1950's Hi-Fi. Jack Smith, 288 Winter Street, N. Andover, MA 01845

WANTED: Military Surplus Radios. We need Collins 618T, ARC-94, ARC-102, ARC-114, ARC-115, ARC-116, ARC-[illegible], RT-1167 or RT-1168, ARC-164, RT-1260, ARC-186, ARN-118, RT-1159-A, MRC-95, 718B-1-2, PRC-26, PRC-[illegible], PRC-[illegible], PRC-77, RT-524, VRC-[illegible] Antenna Coupler, [illegible] CU-1658A, ARC, CU-1669, GRR. Also need maint [illegible] KWM-2A, 516F-2, 312-5, 30L-1, 302C-3 and World War II [illegible] Collins equipment. Top dollar paid or trade for new Amateur gear. Write or phone Bill Slep, 704-524-7519, SLEP ELECTRONICS COMPANY, Highway 441, Otto, NC 28763

RF POWER METER .01-12.4 GHz Narda 8440 $95. Heath Cantenna [illegible] $15. Cannon remote base [illegible] cabinet, perfect for repeater $75. K6KZT, 2255 Alexander, Los Osos, CA 93402

SOLAR ELECTRIC panels and system components. [illegible] Arco panels with 10 year warranty. Lowest prices in country. Catalog $1.00. KA8DSS, Radiant Distributors, 3000 Dorsen, Acton, MI 49301. (616) 874-8899

FOR SALE: Heathkit SB-104 $200, SB-604 w/ [illegible] SB-644 [illegible] SB-634 console $45, HW-2036A 2m $100, [illegible] [illegible] All equipment in good condition. [illegible] 1205 North Main, O'Fallon, MO 63366

10 WATT HF linear amplifier kit. For info SASE to: A & A Engineering, 2521 W. LaPalma Ave. #K, Anaheim, CA 92801. (714) 952-2114

MICROWAVE VCOs Watkins Johnson V901 3.6 GHz to 5.0 GHz $35 postpaid. Send SASE for more info. Stanley Bolte, 2748 Lockwood, Carrollton, TX 75007.

FOR SALE: Hy-Gain #389 Antenna, Tri-Ex W-51 Tower. A. Garcia, 4808 Bergenline Avenue, Union City, NJ 07087. (201) 864-4881

FOR SALE: Collins Equipment: KWM-2 and 30L-1 1 KW. Complete with power supply, 110V and 220V. SM-2 Desk Dynamic Mic. Remote control carrier. Collins Speaker. [illegible] patch. Quad Ant. 80-40-20-10 meters. Carrying cases. Stationside for KWM-2 and 30L-1 Amp. Complete with instructions by Collins. Complete with instructions by US Gvt. [illegible] TM-11-5820-554. Mobile Mount MP-1 (new not used). Mobile pwr sup. 35-D2 (new not used). Mobile Dynamic Mic. MM-1 (new not used). The equipment above in excellent condition. Will sell complete for $1,000.00. Contact William J. Maida, 224 W. Sabal Palm Pl. Longwood, FL 32779 or phone 305-869-0138

HOMEBREW PROJECTS List SASE. PO Box 706, East Hampton, NY 11937

DRAKE TR-7, power supply, 5B filter, N.B., [illegible] complete with manuals. $850.00 plus UPS. K5MEF, 4 Sombrero Lane, St. Rose, LA 70087

UHF PARTS. GaAs Fets, MMICs, trimmers, chip caps, teflon pcb, and other builder parts. SASE brings list. [illegible] components, 11246 Cape Cod, Taylor, MI 48180.

SIGNAL ONE, CX7-B, A spare final, maintenance manual. $850.00 plus UPS. K5MEF, 4 Sombrero Lane, St. Rose, LA 70087

LASERS: Illustrated how-to manual on Ham Radio use of laser. 112 bound pages of practical information, plans, schematics, photos, sources of inexpensive parts. $13.95 ppd. [illegible] Box 1255 Walnut, Ventura, CA 93004

APPLE II/c/e Morse Code Program menu [illegible] [illegible] [illegible] [illegible] etc. Write LARCSCO, PO Box 2018, 1200 Ring Rd, Calumet City, IL 60409. (312) 891-0274

SPECIAL ANTENNAS by K3BFW featuring the RW-1 1.8 MHz beam $49.95 and the KTL [illegible] [illegible] [illegible] SASE for information. Thomas H. Bramer, 1203 Warren St. New Cumberland, PA 17070

SSSSSSUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40 page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102

CABLE TV CONVERTERS & EQUIPMENT. Plans and parts. Build or buy. SASE for information. C & D Electronics, PO Box 1402, Dept. HR, Hope, AR 71801

YAESU OWNERS: Hundreds of modifications and improvements for your rig. Select the best from fourteen years of genuine top rated Fox Tango Newsletters by using our new 32 page Cumulative Index. Only $5 postpaid (cash or check) with $4 Rebate Certificate creditable toward Newsletter purchases. Includes famous Fox Tango Filter and Accessories Lists. Milt Lowens, N4ML (Editor), Box 15944, W. Palm Beach, FL 33416. Telephone (305) 683-9587

MARCO: Medical Amateur Radio Council, Ltd. operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc.) invited to join. Presently over 550 members. For information write MARCO, Box 73, Acme, PA 15610.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, selective calling, text file transfer, customizable full screen logging, 24 programmable 900 character messages. Ideal for MARS and traffic handling. Requires 256K PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019

ELECTRONIC ENCLOSURES. Attractive, reasonably priced. Aluminum top and sides. Walnut stained solid wood ends. Variety of sizes and custom sizes available. Sample $5.00 [illegible] [illegible] [illegible] Frequency Electronics Devices, RR 3, Box [illegible] Fayetteville, AR 72701

NATIONAL RADIO EQUIPMENT [illegible] or NCL-2000 parts [illegible] SASE. [illegible] [illegible] [illegible] [illegible] MA 01907

RTTY JOURNAL—Now in our [illegible] year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL $10.00, foreign [illegible]. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekly net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, NY 10538

RUBBER STAMPS [illegible] [illegible] [illegible] [illegible] [illegible] CA 92[illegible] SASE [illegible] information.

ELECTRON TUBES [illegible] transmitting, microwave, [illegible] type available. Large stock. Next day delivery, most cases. Daily Electronics, PO Box 5029, Compton, CA 90224. (213) 774-1255

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. Hein Specialties, Inc., Dept. 301, 4202 N. Drake, Chicago, IL 60618

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806

CABLE TV CONVERTERS/DESCRAMBLERS Guaranteed lowest prices in US. Jerrold, Hamlin, Zenith—Many others! Lowest dealer prices! Orders shipped within 24 hours! MasterCard, VISA, COD accepted. Free Catalog. Call (800) 345-8927 only. Pacific Cable Co., Inc., 7325 1/2 Reseda Blvd. #1626, Reseda, CA 91335. (818) 716-5914

WANTED: Heath [illegible] [illegible] [illegible] [illegible] Mike W0[illegible]

MORSE CODE Practice program for IBM PC and Compatible. Send $19.95 check to: SiC Microcomputer Co., 1008 Swallow Drive, Cherry Hill, NJ 08003. Developed by KD25M

COMING EVENTS

Activities — "Places to go . . ."

PENNSYLVANIA. JANUARY 18: Amateur Radio Branch, The Chaplains of Delaware Valley, will hold their 7th annual [illegible], [illegible] Apartment Complex, 2240 Benjamin Franklin Parkway, Philadelphia, at 8 AM. Everyone invited. Contact Ron [illegible] W3[illegible] [illegible] or write to [illegible] [illegible] Street, Philadelphia, PA [illegible]. Reservations are necessary.

SOUTH BEND, INDIANA. Hamfest/Swap-It-Shop, January 4, 1987, first Sunday after New Year's Day. Century Center downtown on US 33 Oneway, North to Tower St. [illegible] [illegible] Bldg. and [illegible] Four [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

OPERATING EVENTS

"Things to do . . ."

January 20: Mission Trail Net will celebrate its [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] every night at 2 PM PT. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

Feb 1-2: YL ISSB QSO Parties [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] WA6HLA [illegible]

NEW products

The IC-03AT features 220-224.995-MHz coverage, an LCD readout, DTMF, 2.5-W output (5W optional), ten memories, memory scan, program scan, and 32 built-in subaudible tones. It comes with an IC-BP3 rechargeable battery pack, AC wall charger, belt clip, wrist strap, and earphone.

For information, contact ICOM America, Inc., 2380 116th Avenue N.E., Bellevue, Washington 98009-9029.

Circle #303 on Reader Service Card.

1.3-GHz shirt-pocket frequency counter

OPTOelectronics, Inc. has introduced the model 1300H frequency counter. With an anodized aluminum cabinet measuring only 3-1/2 x 4 x 1 inches, the new unit includes self-contained, rechargeable Ni-Cad batteries, a signal measurement range of 1 MHz to over 1.3 GHz, 8 red 0.28-inch high LED digits, and a BNC signal input connector. Switches are provided for AC or battery operation, fast or slow gate time, high or normal sensitivity and range select: 1-500 MHz or 500-1300 MHz. Resolution to 1 kHz in 0.25 seconds or 100 Hz in 2.5 seconds over the entire range. Accuracy to ± 1 count LSD is achieved with an RTXO time base. Additional features include a "measurement in progress" indicator, calibration adjustment without the need to open the case, and excellent sensitivity.

Priced at $150, the 1300H comes equipped with internally installed Ni-Cad batteries and a 110 VAC/9 VDC adapter for AC operation and charging batteries. Optional accessories include a carrying case, probe and telescoping antenna.

For details, contact OPTOelectronics, 5821 NE 14th Avenue, Fort Lauderdale, Florida 33334.

Circle #304 on Reader Service Card.

C-band/Ku-band receiver

Luxor North America Corporation has introduced the 9993 C/Ku Receiver, a new mid-line block satellite receiver. Decoder-compatible, it's designed to give optimum performance on both C-band and Ku-band.

It has a crisp, bright green front panel LED for display of all basic functions, built-in remote antenna control with three-digit display and a digital signal strength meter.

The 9993 is easily operated by a hand-held, 35-key, full-function, remote control. A three-digit code for lock-out of undesirable channels is controlled via the remote unit. Built-in remote polarity control offers convenience; non-volatile memory is unaffected by power loss.

Video features include functional compatibility with most popular signal decoders, and an optimal TI (terrestrial interference) filter operable by remote control. Built-in AFC maintains optimum signal reception on each channel; fine-tuning can be executed from the remote. The 9993 also has outputs for both tv set and monitor.

Audio features include monaural, discrete, and matrix stereo formats, a three-digit display to indicate tunable audio frequencies, wide and narrow bandwidth switchability, and volume control and muting from the hand-held remote.

For details, contact Luxor North America Corporation, 600 108th Avenue N.E., Suite 539, Bellevue, Washington 98004.

Circle #305 on Reader Service Card.

plug-in CTCSS for handhelds

Communications Specialists, of Orange, California, is currently expanding their line of programmable CTCSS tone equipment that will plug directly in to many popular two-way radios. Two recent additions to this line — adapter kits for the Standard Communications and TAD USA handhelds — utilize the new TS-32HB hybrid-sized encoder-decoder. The Standard 734L/834L may now use a TS-32HBL (low profile) encoder-decoder and a 01-1030 adapter plug. The TS32HBL is priced at $64.95 and the 01-1030 adapter is $7.50.

The TAD M1520-454 uses the TS32HBH (high profile) encoder-decoder and 01-1031 adapter plug. The TS32HB used in these applications employs the popular DIP switch programmability first introduced in 1979 with the company's larger TS-32. The TS32HB uses state-of-the-art hybrid packaging to obtain its small size. A crystal-controlled clock oscillator provides stability under all conditions, and sensitivity is rated at 6mv RMS for use with the lowest output receivers. The adjustable sinewave output is accurate to within ± 0.5 Hz at a level of 6 volts peak-to-peak across 10k.

For details, contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665-4296.

Circle #306 on Reader Service Card.

FEBRUARY 1987 / $2.50

ham radio magazine

packet radio PSK modem for JAS-1

hr

focus on communications technology

ham radio magazine

FEBRUARY 1987

volume 20, number 2

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00; three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service): one year, $37.00
All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 108

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents

REFLECTIONS

looking ahead to the year 2000: 13 more exciting years for Amateur Radio

In last December's "Reflections" we reviewed the past 13 exciting years of Amateur Radio as reported in *HR Report* and *Presstop*. It's hard to appreciate the extent to which Amateur Radio can change in such a short period until you see it summarized on one crowded page. But as the old saw has it, "You ain't seen nothing yet!"

The art and practice of radio communications has been in a state of flux since even before Hertz, Fessenden, Marconi, and a cast of dozens more started seriously experimenting with "the ether" toward the end of the last century. That's certainly not going to change as this century draws to a close. Look for smaller, smarter, more sophisticated, more efficient versions of the kinds of hardware (not to mention embedded software) we're enjoying today — that's inevitable. And, of course, there'll be comparable new technologies. Just as we've seen a tremendous increase of interest in and use of AMTOR, packet radio and, to a degree, spread spectrum (which, by the way, we in Motorola's Military Engineering Division were examining as an option for "secure battlefield communications" a quarter of a century ago), the next 13 years are sure to see the incorporation of both yet — unthought — of new techniques and revolutionary new applications for well-established techniques. For example, one need go no further than AMSAT's exciting Phase 4, which calls for a geostationary satellite (or satellites) uplinked through "gateway" stations all over the globe. Eventually, a handheld-equipped Amateur operating from almost anywhere will be able to call — selectively — any similarly equipped Amateur virtually anywhere else in the world at any hour of the day or night!

However, it's not in the hardware end of Amateur Radio that the most revolutionary things are likely to happen, but in the perception and application of the Amateur Service itself. Like it or not — and this is a trend that's already upsetting a number of thoughtful, dedicated, active, Amateurs — much of what Amateur Radio is today is going to change drastically or even disappear by the year 2000. Examples of some of these possible new directions may be found in the FCC's *Working Paper 20: Alternatives For Improved Personal Communication*, which was released last September. Authored by Jim McNally, WB3APV, of the FCC's Office of Plans and Policy, this provocative study begins with the assumption that there is a need for some form of readily available "personal communication." Furthermore, it asserts that this need is not being met by any current radio service — namely cellular radio or other common carriers, Amateur Radio, 27 MHz CB, or GMRS (for which McNally also holds a license).

This need, greatly stimulated by the CB explosion of the 1970s, isn't going to go away. If anything, it's going to grow, and services that are unwilling or unable to adjust themselves to accomodate at least some of that need are going to lose — both frequencies and support — to those that do.

What this means to Amateur Radio is that we're going to have to learn to take advantage of this evolution rather than fight it. McNally suggests, for instance, allowing an Amateur's family members limited access to some VHF or UHF frequencies, using the Amateur's callsign. At the same time, there'd also be a correlated relaxation in the limits of "permitted communications." Maybe — at last — we'll even be able to use the autopatch to order a pizza or warn the boss we'll be late for work because of a traffic jam!

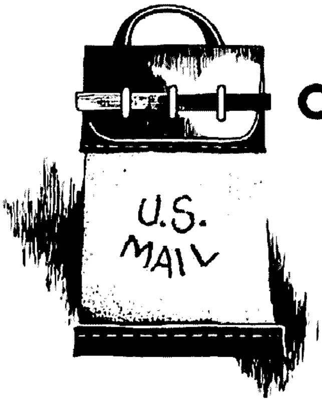
Of course, the concept of the Amateur as an experimenter and/or professional communicator isn't going to go away. If anything, it's likely to expand as a more broadly conceived Amateur Radio Service attracts a more diverse group of users who can bring new skills and applications to what is, even today, too widely perceived as a narrow, *elitist hobby*. Though the popular image of an Amateur cloistered in his basement workshop, punching holes for a new rig in a bread pan chassis, will fade before a growth pattern dominated by entry-level "Communicators" talking through UHF handhelds, there'll still be plenty of room for EME or meteor scatter experimenters, hf traffic handling and DXing, and the kind of all-encompassing technological sophistication that created OSCAR 10 and conceived Phase 4.

Though all this may seem to be radical "pie-in-the-sky" fantasizing to some Amateurs, consider the following: greatly enhanced Novice and Tech privileges are in process at the FCC and may well have been adopted by the time this issue leaves the press. Furthermore, though code-free Amateur license proposals have been knocked flat a couple of times, the concept of further relaxing entry-level Amateur code requirements isn't "out." The Amateur community has demonstrated to the FCC that it is fully capable of running that most vital function of the Amateur licensing program, Amateur examinations. As a result, the Commission is now seriously considering delegating responsibility for issuing Amateur callsigns to the private sector. The long-term implications of this seem obvious — ever-increasing responsibility for self-maintenance and operation, by the Amateur service.

The logical result of all this could very well be — even before the year 2000 — a larger and broader-based, self-administered Amateur Radio Service. Are we ready for such radical change? I hope so!

The next 13 years promise to be most interesting ones for Amateur Radio. Unfortunately, based on the current age profile and the actuarial tables, a shocking proportion of us won't be around long enough to see the new century in and, consequently, all these exciting new developments in Amateur radio, come to pass. I hope I am, and I hope you will be as well.

Joe Schroeder, W9JUV
Associate Editor



comments

welcome KB2BRL

Dear HR:

My name is Colleen Brady, KB2BRL. I am only 10 years old!

I first got started in learning to be a Ham this past summer. My Dad is an Amateur and I thought that it would be great to get a license too. I wanted to get my license before, but I still needed some more math in school. I have been working on code for a couple of years, but really did serious studying this past summer.

When I started to learn the theory I was surprised that we were covering some of the same things in school. My fifth-grade class was studying powers of 10, and I found out I had a use for them. Now I can note my frequency or even understand what a milliamp is by using 10 to the −3. I told my teacher, and I had the chance to explain how this math can really be useful, and that I was studying to get my license. Another area that I can use both at school and at home is geography. Now not only can I learn maps and countries in school, but I can use them at home too. On only my third contact I had a QSO with HK3IKP in Bogota, Columbia. The other kids in class have studied SA and Columbia, but I have had the chance to *talk* with Columbia! I am doing a Science report on sun spots, because we have studied these in school. My report will be a bit different than the others, since mine will talk about sun spots and propagation with radio waves. I guess there are some things in school that you can use.

In my first month as an Amateur I have had the opportunity to talk with 22 states and two countries. It seems that every time I get on there is a new place to look up on the map. Now I look forward to receiving QSL cards in the mail from these contacts. When learning the Morse Code I found it to be difficult at first. Now, even though it is still difficult at times, it is a lot of fun, and I look forward to making yet another QSO using this form of communications.

I feel I'm a lot luckier than other kids who may want to become a Ham. My Dad, WB2WPM, already has all the equipment. We operate a Kenwood TS-440S, a Cushcraft A-3 Triband, and dipoles for 40 and 80 meters. There's a lot of other equipment too, but until I upgrade I won't be able to use it. I am looking forward to finding an upgrade class this fall so I can get my General class license.

In the picture enclosed you can see my good friend "Lasagna," our 6-month-old Cocker Spaniel. Besides my Dad, my Mom has her Novice license too, KA2TDG. My 8-year-old sister has an interest in being a Ham too. In a year or so I will be able to start to teach her the things she will need to know, so she can have a license too.

Colleen M. Brady, KB2BRL
East Aurora, New York 14052

wanted: M800 RTTY program

Dear HR:

Does anyone have an M800 RTTY program for the TRS80 Model 3 that they're willing to share?

Bernard Gayrard, F6HGB
"Lou Bouls" Laa-Mondrans
64300 Orthez, France

HORANT for CP/M

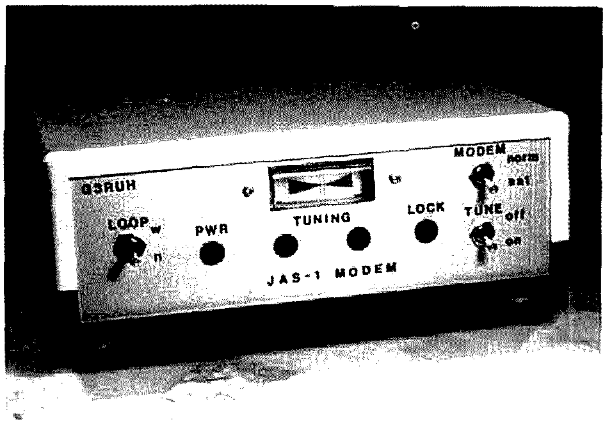
Dear HR:

Regarding the HORANT program in the October, 1986, DX Forecaster (page 92), I'm sure that you've received many comments on the footnote giving a substitute for ARC SIN (ASN). I use a CP/M version of MBASIC; substituting

*ASIN(Y) = ATN(Y/SQR(1 − Y*Y))*

works fine. Looks like a useful program. Thanks.

Jack G. Hines, K4GIO
Vienna, Virginia 22180



Access the world's first flying mailbox with your TNC

a packet radio PSK modem
for JAS-1/FO-12

JAS-1, or "Fuji," the first totally Japanese Amateur Radio satellite, was launched flawlessly on August 12th, 1986, from Tanegashima Space Center, located on an island off the southern tip of Japan. It carries two transponders: a traditional one for voice and CW, and a second that functions as the first spaceborne store-and-forward packet radio mailbox. In orbit a thousand miles above the earth, it's inclined at 50 degrees to the equator, with a period of 120 minutes, offering users an aggregate 2 hours of communication per day.

Suppose you want to send a message to someone halfway around the world. You simply send a message to the mailbox, and in less than an hour it's available for retrieval by your addressee.

equipment

What do you need to use the mailbox? In **fig. 1** you'll see that four components are required — a pair of radios, a modem, an AX.25 protocol Terminal Node Controller (TNC) and a terminal. Regular OSCAR users with packet radio stations will have everything shown except the box labeled "modem." Terrestrial packeteers will certainly have the 2-meter equipment and may well have 70-cm SSB receive capability, together with a steerable Yagi. Elevation rotation is highly desirable, but by no means essential; much of any 20-minute satellite pass is low enough to be within the vertical beamwidth of even modest antennas.

Few stations, however, will have the special FO-12 modem. The built-in Bell 202 1200 Baud AFSK modem (modulator/demodulator) found in standard TNCs *cannot* be used with JAS-1/FO-12. You'll have to dis-

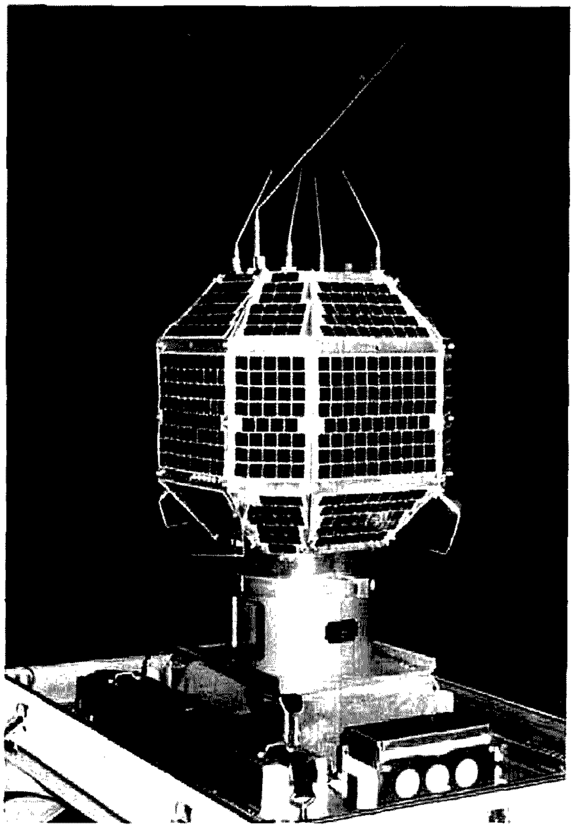


Photo A. Launched in August, 1986, JAS-1 ("Fuji") *carries an* AX.25 packet radio mailbox. (Photo courtesy JARL)

By **James Miller, G3RUH**, 3 Benny's Way, Coton, Cambridge, CB3 7PS, England

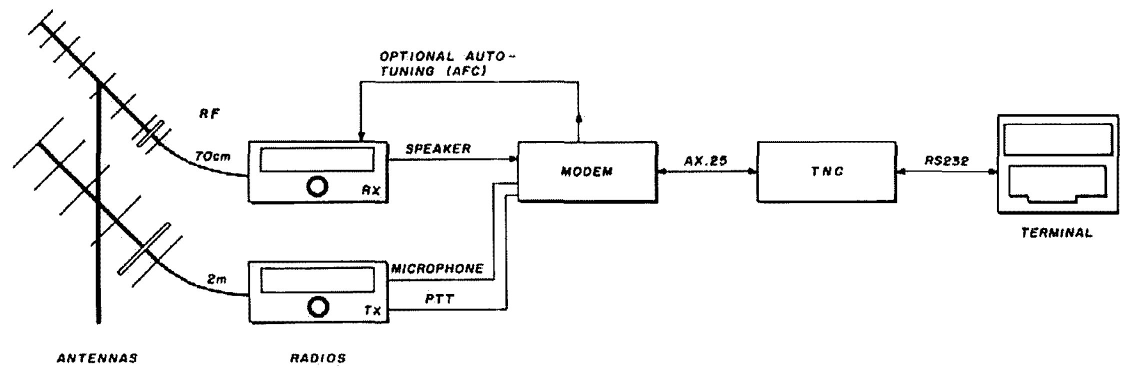


fig. 1. Basic packet station requires addition of special modem for direct JAS-1 operation.

connect the internal modem and substitute an external modulator/PSK demodulator such as the one described in this article. This isn't particularly difficult. Just build the circuit, link it to your TNC with only four or five wires, adjust the audio connections, and the global mailbox is yours to enjoy!

Note: this modem is suitable for your TNC only if your TNC's internal modem can be bypassed. Both the TAPR-1 and TAPR-2 designs allow this (as evidenced by the HD-4040, AEA's PKT-1 and PK-80, Pac-Comm's TNC-200, GLB's TNC2A, and the MFJ 1270, for example).

If your TNC isn't based on the TAPR design, you may nevertheless be able to intercept the RXdata, TXdata and TXclock from their internal modem by cutting tracks. If this appears to be impossible, your best option may be to build a TAPR TNC-2 kit and integrate it with this JAS-1/FO-12 modem, thereby creating a satellite-dedicated TNC.

link format

For reference, here's a brief technical summary of the JAS-1/FO-12 link format. I'll explain unfamiliar terms as we go along:

You receive on 435.910 MHz, SSB/CW mode, in a 2.4 kHz bandwidth. The doppler shift will be up to ±8 kHz, and there is a rate of change up to 40 Hz per second on the highest elevation passes. You transmit on 145.850, 145.870, 145.890, or 145.910- MHz fm; doppler shift correction is unnecessary. An uplink effective radiated power of 100 watts (for example, 10 watts to a 10-element Yagi) is quite sufficient.

The uplink modulation is fm; the downlink is Phase Shift Keying (PSK). Data rates are 1200 bits per second, normal packet NRZI, except that the uplink is exclusive/ored (EXORed) with its own 1200-Hz clock.

modem description

This modem has been designed with as much flexibility as possible so you can tailor it for your particular application. As illustrated in **fig. 2**, it consists of an *uplink modulator*, a *downlink demodulator*, an automatic UP/DOWN *tuner* to track changing doppler shift on receive, and *power supplies*. **Table 1** lists the modem's specs.

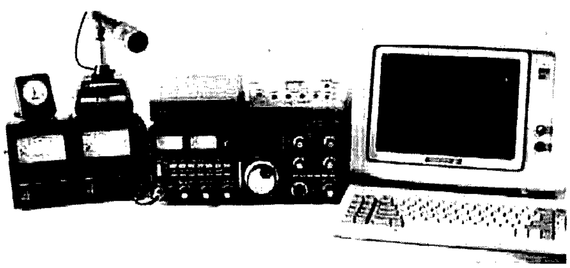


Photo B. G3RUH packet radio/satellite station. System components are linked as shown in fig. 1.

The uplink modulator (U1 and U6) takes the signals TXdata (transmitted data) and TXclock from the host TNC and combines them into the TXaudio (transmit audio) signal for the 2-meter fm transmitter. As shown in **fig. 2**, signals flow from right to left. U1 pins 3 and 11 are used as non-inverting buffers. Diodes D1 and D2 prevent U1 from overloading the TNC when the modem is switched off. Note that the modulator ICs use a 5-volt, rather than a 12-volt, supply.

From a TNC-1, TXclock is at 32 times the bit rate. For a TNC-2, it's 16 times, so link LKC selects the correct division ratio from divider U6. The 1200-Hz clock produced at test point TP4 is kept in phase with the data stream by resetting divider U6 on every data transition. This is done from U1 pin 10 and R6-C1, which generate short 16-μsecond pulses. Clock and data are EXORed (this is called "Manchester Coding") in U1

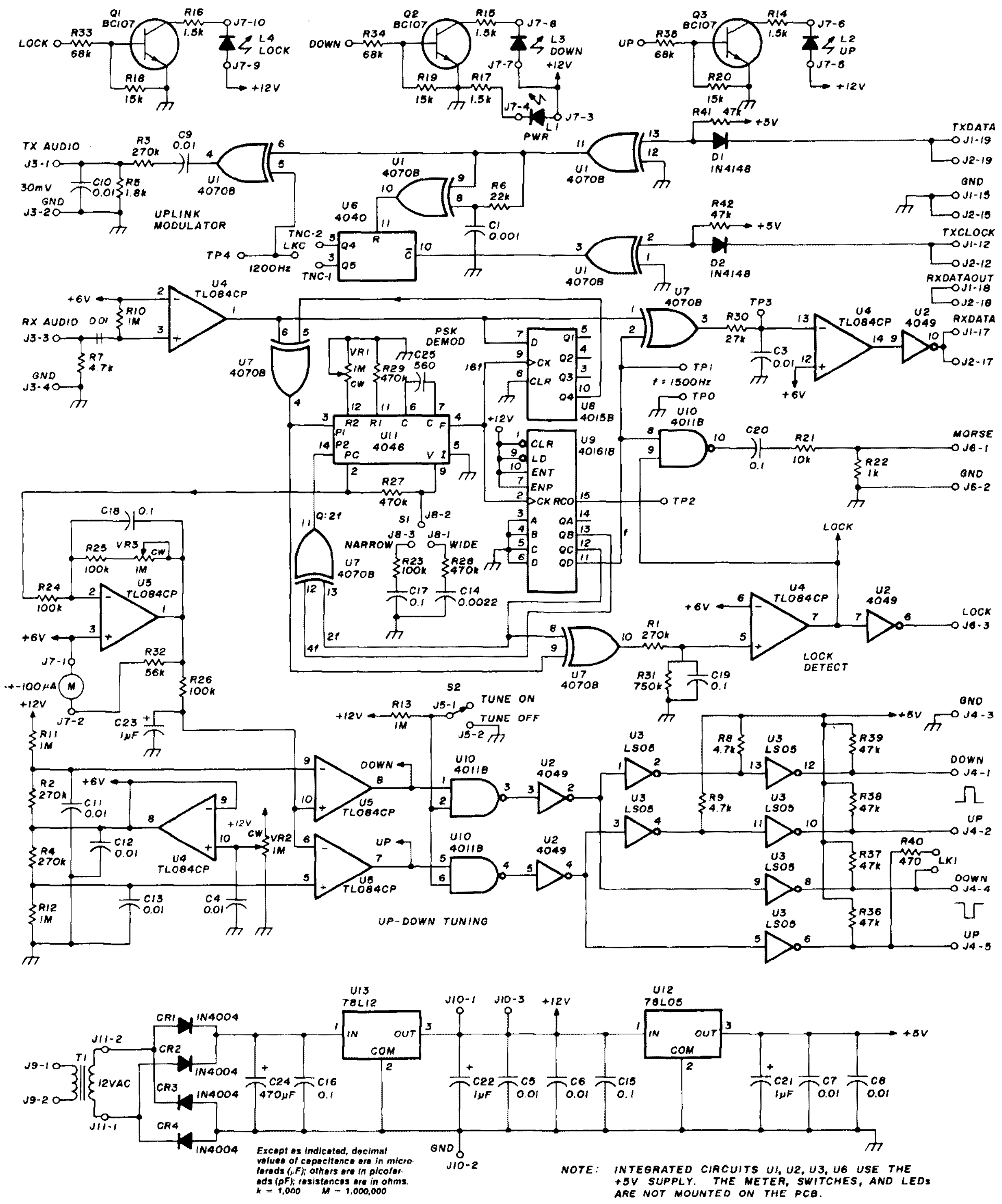


fig. 2. PSK packet radio modem schematic. Modem consists of uplink modulator, downlink demodulator, automatic UP/DOWN tuner, and power supplies.

pins 5 and 6, and the 5-volt peak-to-peak signal at U1 pin 4 is then filtered down to about 30 mV. You can reduce the output voltage if necessary by increasing R3. Superimposing a 1200-Hz clock on the data in this way simplifies the satellite's own electronics considerably.

Note: you may recognize Manchester coding as just PSK in disguise! You can, therefore, use this modem for experimental PSK communication. This subject will be addressed under the heading, "use for terrestrial PSK packet" below.

Considerable effort has gone into the development of the *downlink demodulator* in order to meet the goals of elegance, robustness, simplicity, ease of alignment and testing, minimum number of discrete components, and proper matching to the FO-12 signal characteristics. While it owes its origin to my earlier OSCAR-10 demodulator,[1] it was, in fact, not actually selected until a number of other candidates — both simpler and more complex — had been evaluated.

In contrast to conventional local packet radio, which uses two tones (AFSK) to signal binary 0 or 1, FO-12 uses PSK modulation. The carrier signal PHASE is changed 180 degrees (inverted) when a change in binary level is signaled. You can think of this as using a phase of +90 degrees for "0" and −90 degrees for "1," or vice versa. Either is acceptable because the TNC is interested only in changes.

To demodulate phase-shifted signals you need a phase reference and a phase detector. ICs U7, U8, U9 and U11 recover this reference "carrier" (available at TP1) from the signal. EXOR gate U7 pins 1 and 2 form the phase detector, the output of which is filtered (TP3), limited, level shifted and output to the TNC as RXdata.

A simple phase-locked loop (PLL) can't be used to recover the carrier from a PSK signal because with random data there's no discrete frequency available for a loop to lock onto. Most PSK demodulators have to rely on some non-linear multiplicative processing instead. The recovery circuit used here is a digital "squaring loop."

U4 pins 2, 3, and 1 are a limiter, which simply makes all subsequent signal processing digital. The limited signal is multiplied by itself delayed by 1/4 cycle. The delay is provided by 4-bit shift register (U8), which samples the signal at its pin 7 and is clocked at 16 times the carrier frequency. The multiplication happens in EXOR gate U7 pins 5 and 6. This creates (at U7 pin 4) one cycle of twice the carrier frequency for every zero crossing of the signal. Mathematically we can say the signal is:

$$\cos\ (\omega t \pm \frac{\pi}{2})\ ,$$

with the + or − corresponding to data 0 or 1. So the effect of this multiplication is (ignoring amplitude):

$$\cos\ (\omega t \pm \frac{\pi}{2}) \times \sin\ (\omega t \pm \frac{\pi}{2}) =$$

$$\sin(2\omega t \pm \pi) = \sin\ 2\omega t$$

or

$$signal \times delayed = constant\ phase\ at\ 2\ \omega$$

The phase-locked loop U11 runs at 16 times carrier frequency. With associated divide-by-16 U9, it locks onto U7 pin 4's double frequency signal, providing a smooth recovered carrier at U9 pin 11. Wide and narrow loop bandwidths can be selected with switch S1 to facilitate initial signal acquisition (use optional).

Recovered carrier, which will be around 1500 Hz, is applied to phase detector U7 pin 2, together with the received signal at pin 1. If they are (for example) in phase, U7 pin 3 will go low, with residual noise being smoothed away by R30-C3. The following op-amp, is used as a comparator/limiter, which then drives 12 volts to the TTL level converter, U2. Signal RXdata then goes off to the TNC.

Two additional circuits complete the demodulator. It's valuable to have a "LOCK" indication. A simple EXOR gate, U7 pins 8 and 9, provides this by multiplying the PLL stimulating doubled-carrier frequency signal by the recovered *2f* signal from divider U9 pin 12. When locked, U7 pin 10 goes high. U4 pins 5 and 6 form a threshold detector, which then drives LED L4 via Q1.

When not in mailbox mode, the satellite sends telemetry in Morse code on 435.795 MHz. Spare gate U10 pins 8 and 9 have simply been wired to provide a regenerated Morse output for (optional) computer use.

With the exception of output buffer U2, the demodulator operates from 12 volts.

This PSK demodulator is completely aperiodic. Its operating frequency is set by VR1, and could in principle operate at the i-f. As shown it tunes from approximately 700 Hz to 70 kHz. The tracking bandwidth is set by R29, and is nominally ±250 Hz. Designed loop bandwidths are 20 Hz and 100 Hz, with a damping factor of 0.7. Data rates faster than 1200 Baud are accommodated by reducing R30 accordingly.

auto-tuning

The received signal frequency changes considerably as a result of doppler shift; a total swing of 16 kHz is typical, with rates of change peaking at 40 Hz per second. Tuning a receiver by hand, maybe even adjusting rotators at the same time, *and* operating a data terminal keyboard clearly poses some logistic problems!

A solution is provided in the auto-tune circuits, which work by activating the UP/DOWN signals of your receiver. They are designed to suit all known ICOM, Kenwood, and Yaesu standards. All differ,

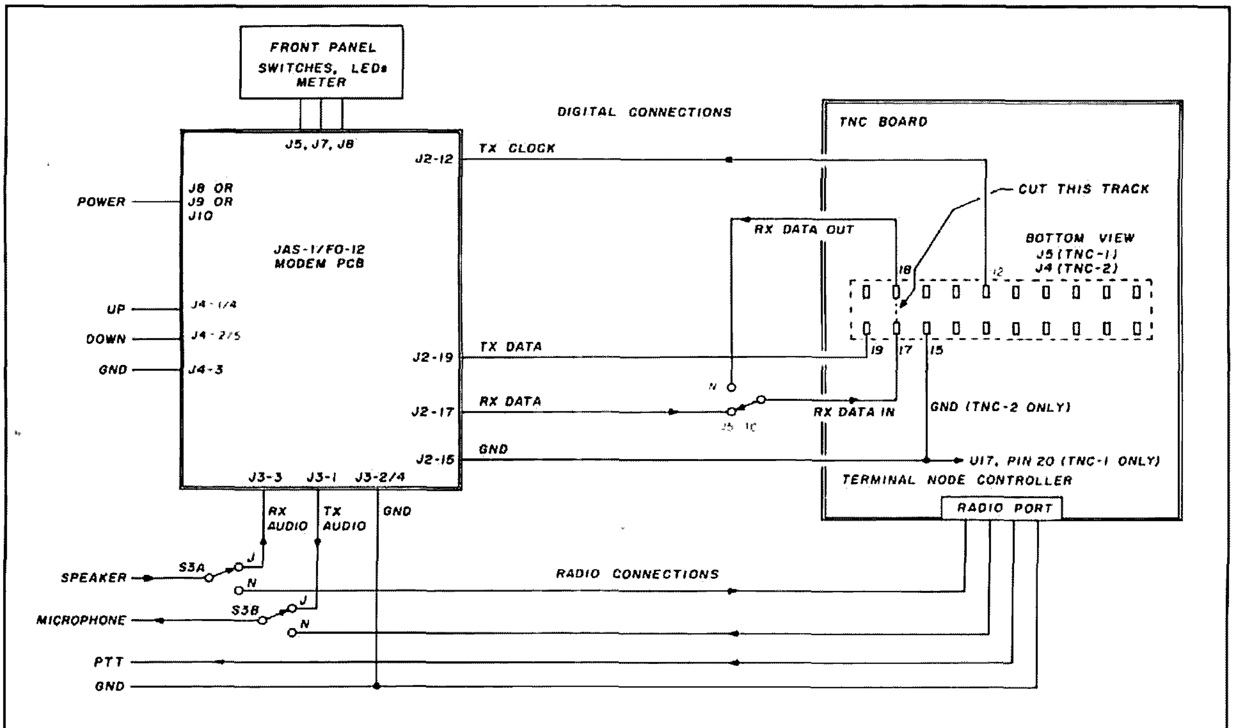


fig. 3. Typical JAS-1 installation, showing connections between radio, modem, and TNC.

Table 1. JAS-1 FO-12 Modem PCB specifications.

Modem:

Downlink: input 50mV to 5-volt rms RX audio. PSK demodulator to TTL digital, 1200 bps.

Uplink: 1200 bps Manchester encoding modualtor to Mic level (about 30 mV p-p) TX audio. RX carrier LOCK LED indication Selectable loop bandwidth. Morse code regenerator.

Connects to AX.25 TNC MODEM DISCONNECT jack. Suitable for TAPR TNC-1 or TNC-2, (and any other, provided the internal modem can be bypassed). TNC digital connections needed include TXdata, RXdata(in), RXdata(out), TXclock, GND.

Digital AFC: tracks changing doppler shift via the UP/DOWN signal lines of your RX rig. Designed for all known ICOM, Kenwood, and YAESU standards. Adjustable for 10-100 Hz per step. Positive pulses, negative pulses, and ICOM bi-level. Tracking ON/OFF switch. Manual tuning indication by LEDs and center-zero meter.

Set-up: three preset pots – for PLL frequency, local 6-volt supply, and UP/DOWN tuning gain.

Power: ac line, built-in PSU; 12-volt ac input; or 12-14 volts dc, a 40 mA.

PCB: 160 by 100 mm (single eurocard) double-sided, plated-through, labeled with instructions. Standard CMOS and LSTTL used. No hard-to-get parts.

even between models from the same manufacturer.

The VCO tuning voltage (about 20 mV/Hz) from U11 pin 2 is amplified by U5 pins 2 and 3, which have gain adjustable from x1 to x10 by VR3. This op-amp also drives a center-zero tuning meter. After filtering by R26-C23, the voltage (which increases for fall-

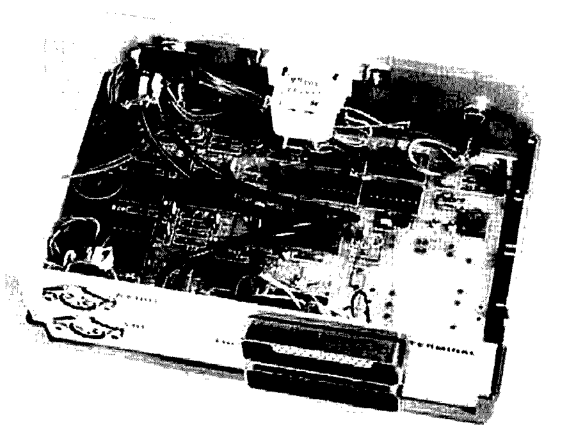


Photo C. Interior and backplane view of modem, showing connectors to radio, TNC, and terminal.

ing frequency) is offered to two comparators, with upper and lower thresholds set by resistor chain R11-R2-R4-R12, 1.28 volts above and below the 6-volt reference. When exactly on tune, outputs U5 pins 7 and 8 are low. If off tune, then the appropriate comparator output goes high.

U10 pins 1, 2, 5, and 6, if enabled by Tune ON switch S2, pass the signal via 12 volts to the 5-volt level shifter U2 to the open collector hex inverter U3,

Table 2. Parts list.

C1	0.001μF, 10 percent
C2-13	0.01μF, 10 percent
C14	0.0022μF, 10 percent
C15-20	0.1μF, 10 percent
C21-23	1μF 16-volt tantalum
C24	470μF 25-volt
C25	560 pF, 5 percent
CR1-4	1N4004, etc.
D1-2	1N4148, etc.
DS1-4	LED 10mA
J1	Standard 20-pin IDC Male PCB header, straight (vertical) or right angle. Straight: RS 471-058, 3M 3428-6202JL or 3592-6002JL, Ansley 612-2024 or 609-2027. Right-angle: RS 471-137, 3M 3428-5202JL or 3592-5002JL, Ansley 612-2004 or 609-2007, and many others – e.g. Fujuitsu, Berg, ITT Canon, BICC Vero, etc.
J2-J11	Terminals (about 30) for external connections. Can also use 0.1-inch pitch (center-to-center hole pattern) SIL connectors, (1x2 pin, 5x3pin, 1x4pin, 2x5pin, 1x10pin).
M1	±100 μA meter, RS 259-549, Farnell 143-510
Q1-3	BC107, 2N3904, etc. (NPN)
R1-R4	270 k
R5	1.8 k
R6	22 k
R7-9	4.7 k
R10-13	1 M
R14-17	1.5 k
R18-20	15 k
R21	10 k (all resistors are 5 percent)
R22	1 k
R23-26	100 k
R27-29	470 k
R30	27 k
R31	750 k
R32	56 k
R33-35	68 k
R36-39, 41,42	47 k
R40	470 ohms
S1-2	SPDT toggle switch
T1	12-volt, 3VA Transformer, RS 207-829, Farnell 141-471
TP0,1,2, 3,4	test points
U1,7	4070 Quad Exor
U2	4049 Hex Inverter Buffer
U3	74LS05 Hex Inverter O.C.
U4-5	TL084 Quad op-amp
U6	4040 12-stage divider
U8	4015 Four-bit shift register
U9	40161 Divide-by-16 (MC14161)
U10	4011 Quad two-input Nand
U11	4046 Phase Locked Loop
U12	78L05 5 volt Regulator
U13	78L12 12-volt Regulator
VR1-3	1M Trimmer, 3/8-inch square, flat mounting: RS 187-321, Dubilier D79-30, A-B E2B, Bourns 3386F, Spectrol 63-M or 63M-T-607

LKC, LKI are made from hookup wire

Modular PSU is 12-volt, 100mA (RS 591-281), Farnell 147-545 and others.

NOTES:

The meter, LEDs, and switches are not mounted on the board.

Power supply components T1, CR1-4, C16, C24, U13 (or modular PSU) are optional.

Use of an IDC connector is not obligatory.

Capacitors: 560-pF, 0.4-inch pitch, ±5 percent polystyrene; 0.001-0.1, 0.2-inch pitch, 10 percent dipped ceramic or polyester, 63 to 100 volts typical. 1μF, 0.2-inch pitch, bead tantalum. 470μF 25-volt electrolytic, 1.2-inch pitch, 1.0 x 0.4 inches.

Resistors: Carbon film, 0.25- or 0.5-watt, 0.4-inch pitch.

which creates two pairs of signals. These are high-going UP/DOWN tune signals at J4-1, J4-2, and low-going signals at J4-4, J4-5. All can sink up to 8 mA.

You have to choose the set that suits your rig by referring to your owner's manual. For example, the Yaesu FT726R needs high-going signals, while the Yaesu FT790R uses low-going. The Kenwood 9500 needs low-going. ICOM has a special bi-level standard for the IC741 and similar rigs, where a 0-volt low signals up, and a 1.3-volt level means down, and neither (about 4.2 volts) means no action. So for ICOM rigs, install link LKI, and use J4-5 . . . unless the microphone is left connected. In this case, the link can be omitted, because an R40 will be connected inside the mic housing.

For many rigs that use low-going pulses, the pull-ups R36-R39 can be omitted. You may also have to experiment with the Scan control settings on the receiver. Some rigs tune in 100-Hz steps, others in steps as small as 10 Hz – hence the reason for including an adjustable gain control (VR3).

power supplies

Flexibility is provided so you can choose your own power supply arrangement: either 12 to 14 volts dc, stabilized at 40 mA, or 12 volts ac (about 0.5 VA), or ac mains (line) or a modular encapsulated PSU.

If you supply 12-volt dc (probably the same as used by the TNC), then fit all components on the circuit diagram to the right of U13 (i.e., C22, C5, U12, etc.). Connect power to J10 pins 1 and 2. Pin 3 is 12 volts, too, so if you use SIL (single in-line) connectors, a reversed plug won't lead to disaster.

If you have a 12-volt ac supply, then connect to J11 and fit all the PSU components shown on the bottom of the circuit diagram. The voltage on C24 should nei-

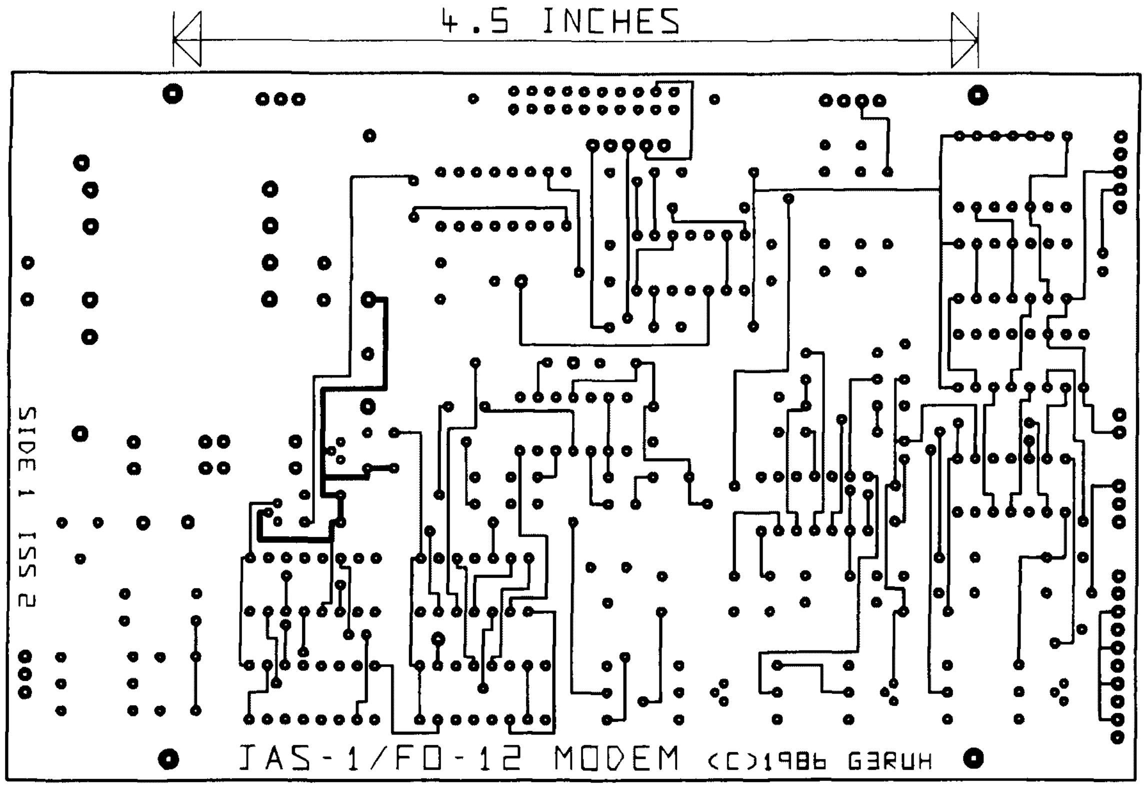


fig. 4A. PSK packet radio modem: top board art (side 1, full-scale).

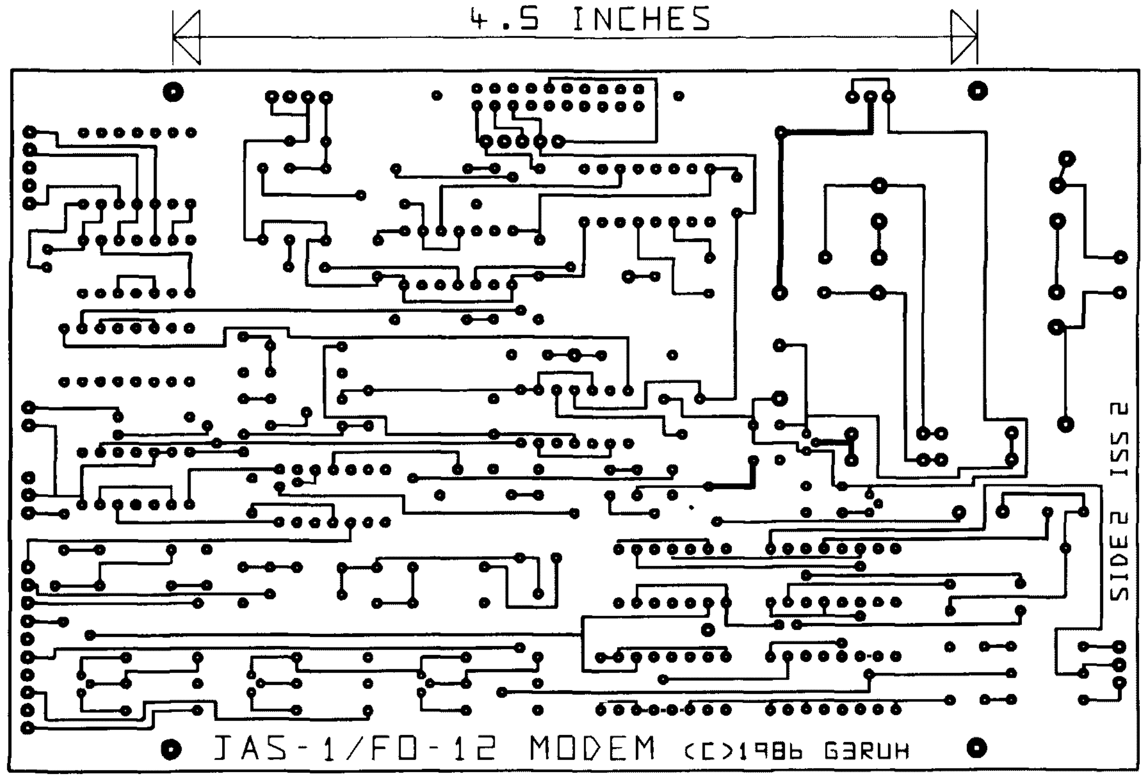


fig. 4B. PSK packet radio modem: bottom board art (side 2, shown full-scale).

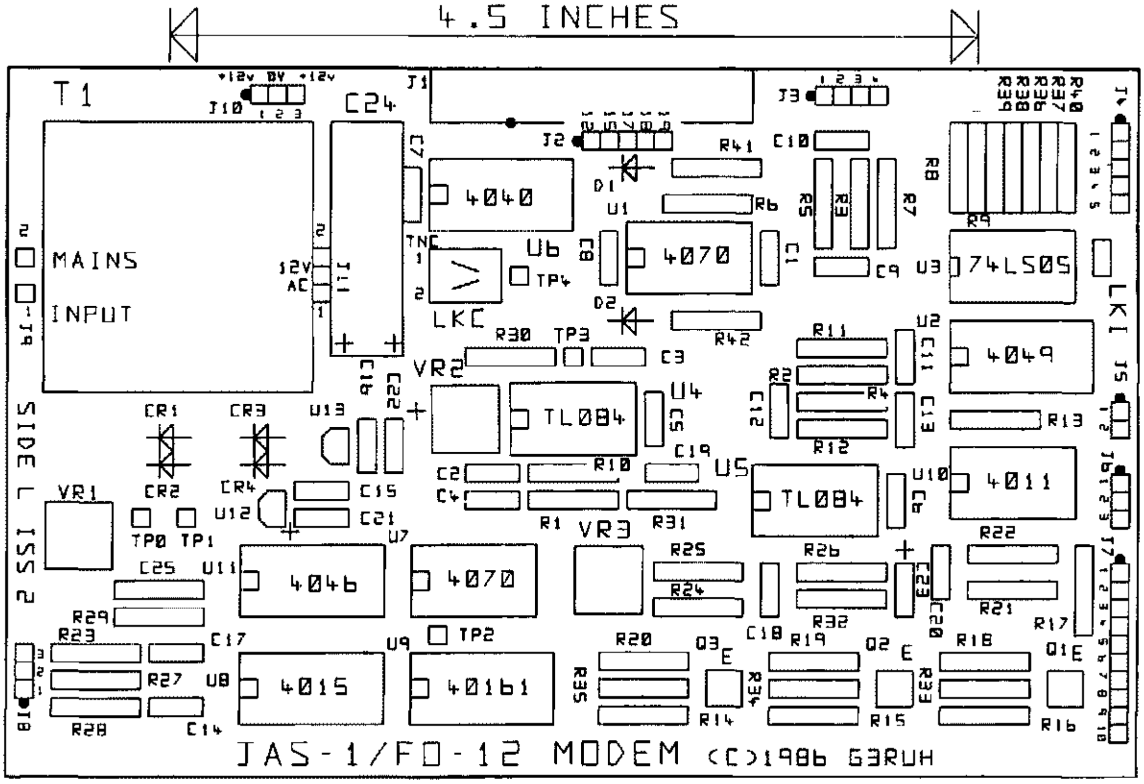


fig. 4C. PSK modem: component layout diagram, shown superimposed on side 1 art. Note components are placed on side 1.

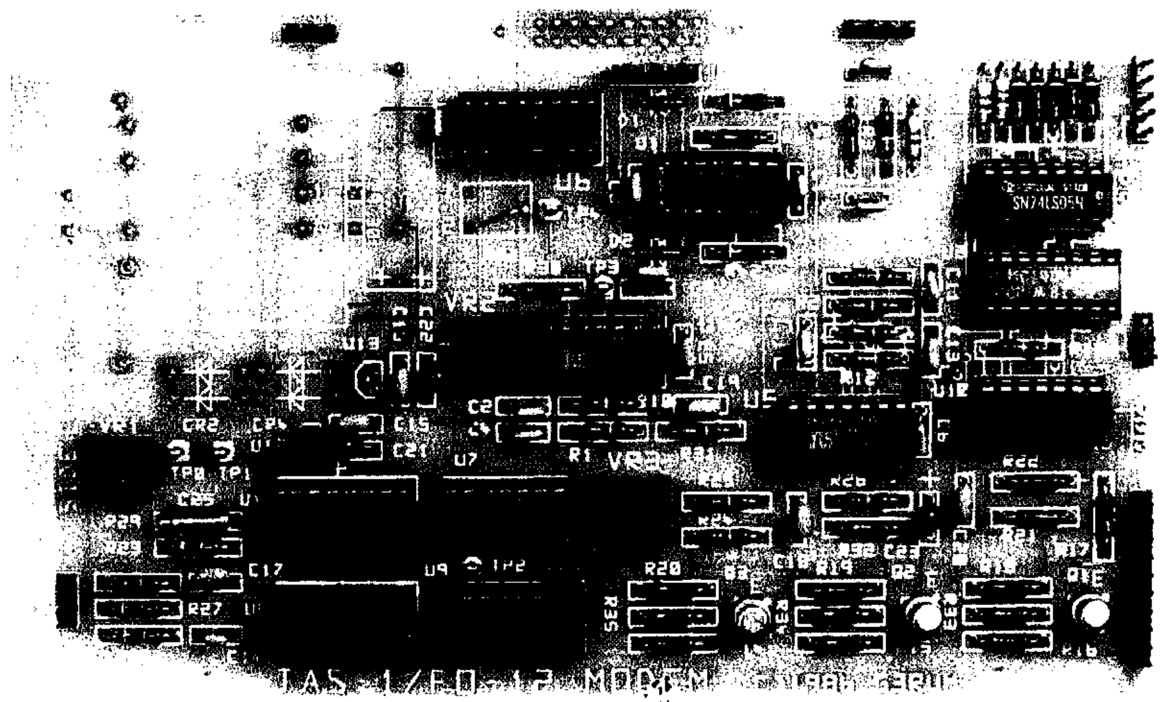


Photo D. Completed circuit board. AC power supply components have been omitted; link LKC is shown for a TAPR TNC-2.

ther drop below 14.9 volts at full load nor exceed 22 volts.

The associated transformer can probably be screwed to the PCB, though you may feel it wiser to place it remotely. The board is drilled for the specified T1, and also for a popular modular PSU (see parts list, **table 2**). Line voltage is applied to J9, at the edge of the board.

If there is 110-volt or 230-volt ac power on this PCB, *you must exercise caution any time the circuit is removed from its enclosure.*

connecting the modem to your system

The modem can be connected to the rest of the system in a number of ways; the minimum requirements are shown in **fig. 3**. First decide whether you're going to use connectors or hand wire it. Select the type of connectors and/or cable you plan to use, and where you're going to locate the PCB. Do you want to dedicate the TNC and modem solely to the satellite application? If so, you could install the PCB permanently within the TNC housing. Do you want to be able to restore instant terrestrial (normal) operation? Then you'll have to use a multi-pole changeover switch (S3) to do this, and put the modem in a properly rf-screened box.

For the radio connections (speaker, mic, and PTT), a socket identical to the one on your TNC can be provided on the modem enclosure, with the signals passing to the changeover switch S3 and then — via a hand-wired connection or another connector plus jumper lead — to the TNC radio port.

connecting to the TNC

The connections necessary for replacing the TNC's standard internal modem with this one are provided on the TNC board at the so-called "Modem disconnect Jack," labeled J5 on the TNC-1 and J4 on the TNC-2. There is no actual connector; the pinout was designed by TAPR to accept a 20-pin IDC plug if required. (See **table 3**.)

Four connections are essential; TXdata, RXdata(in), TXclock, and GND. One PCB track must be cut. A fifth connection — internal modem's RXdata(out) — may also be brought out if you want to be able to restore standard operation with a remote switch. (See **fig. 3**).

Ironically, there's little point in using a 20-conductor ribbon cable if you house the modem in an external enclosure, because screening ribbon is rather messy, and only four or five of the 20 wires are used anyway. However, if your new modem is placed *inside* the TNC enclosure, then it's worthwhile using. For this reason, a 20-conductor IDC facility, J1, has been provided on the PCB. But you'll probably prefer to use J2 instead.

If an external modem is used, select your own method of entry into the TNC enclosure. There are lots of spare pins on the RS232c D-25 wire connector — enough for five digital signals, plus two more for 12-volt power. Choose your pins very carefully, checking that there will be no clash with the regularly used services. I'd suggest pins 12, 15, 17, 18, 19, and 13, 25. Shield all the connections between TNC and the JAS-1/FO-12 modem.

construction

The ready-made PCB for this project is double sided, plated through, and labeled. Full-scale artwork is detailed in **figs. 4A, B,** and **C**. Board and component sources are provided at the end of this article.

The usual caveats apply when assembling the board. Use a fine-tipped iron and fine-gauge resin-core solder. Proceed methodically, checking each soldered joint for integrity immediately after you've done it. Sloppy soldering might send 12 volts back to the 5-volt TNC logic, which will give you no pleasure. I know, I've done it!

Good soldering will flow smoothly through the holes and be visible from both sides. All component leads must be bright and shiny. Any junk box parts — and the PCB as well, if it's been handled too much — will probably need cleaning.

IC sockets are strongly recommended.

If you do manufacture your own non-plated-through PCB, you'll have to drill about 500 holes measuring 0.032 inch (0.8 mm) on the small pads and 0.048 inch (1.2 mm) on the large. Remember to solder every component on both sides, and note that there are 31 through-holes to be wired. Do these first; some will be hidden by components. In addition, if you omit *any* components, you must also install through-wires in their place. Before fitting IC sockets, make sure they're of a type that can be soldered on both sides (many can't) and carefully check for accidental solder bridges between adjacent pins.

Fit components in *ascending* order of height: diodes, resistors, IC sockets, capacitors, trimmers, transistors, and connectors (if you want them). Observe polarity of C21-C24 and all semiconductors. Do not install ICs yet; install them only after PSU testing. Note that the meter, LEDs, and switches are not mounted on the board.

Wire connections to the PCB can simply be soldered into the holes round the board's edge. Note, however, that these holes are spaced 0.1 inch apart to allow for the optional use of SIL plugs and sockets.

For the finishing touch, deflux the board, using a solvent such as 1:1:1 trichlorethylene or alcohol. Besides improving the board's appearance, this will help expose any solder defects. Further excellent advice can be found in reference 2, which also provides useful packet radio information.

Table 3. TNC connections.

TNC-1	J5 Connections	TNC-2	J4 Connections
12	TX Clock Out	12	TX Clock Out
*	Ground	15	Ground
17	RX Data In	17	RX Data In
18	RX Data Out**	18	RX Data Out**
19	TX Data Out	19	TX Data Out

Cut the track between pins 17 and 18.

*Unfortunately TNC-1 does *not* provide a ground pin on J5. Find a local point, such as the WD-1933 chip (U17) pin 20.
**Optional

final checkout

You will need an oscilloscope, an audio signal source and a multimeter. A frequency counter is desirable, but not essential.

Assuming there are no faults whatsoever, just three preset pots need to be adjusted. However, you should also perform the further tests. The meter, LEDs, and switches must be wired to the PCB. *Do not attach the TNC or radios at this stage.*

First remove all the ICs (U1-U11). Connect the power supply of your choice, verifying that a regulated +12 volts is maintained at J10 pin 1. Verify that +5 volts is found on pin 1 of U2. *Do not proceed if these tests fail.* If they do, you have a power supply problem, which obviously must be fixed first. Check for solder bridges or faulty or misplaced components.

initial alignment

1. Set VR1, VR2 and VR3 to their mid-positions. Set the Loop Bandwidth switch (S1) to NARROW and the Tune switch (S2) to OFF.

2. With power off, insert all ICs. Switch on the power, verifying that both 12-volt and 5-volt supplies are still present. The POWER LED should come on. Ignore all other LEDs.

3. Measure the frequency at TP1, adjusting VR1 until this becomes 1500 Hz; frequency increases clockwise. TP0 is a ground (0 volt) terminal.

4. Adjust VR2 (with VR3 at mid-travel) so that the meter is exactly centered.

5. Set VR3 fully clockwise, re-adjusting VR2 if the meter moves from center. Reset VR3 to mid-position. Neither UP, DOWN nor LOCK LEDs should be lit.

6. Connect a 1500-Hz audio generator at a level of 100 mV to 5 volts rms to the RX audio input, J3-3/4. The LOCK LED *should light. If the frequency is high,* the UP LED will light, with a corresponding movement of the meter. Vary the frequency and check that the DOWN LED lights appropriately.

7. Fine adjustment of the auto-tuning UP/DOWN sensitivity control VR3 is done later.

8. Now for a vital safety check: measure the voltage on every pin of J1, J2, J3, and J4. They should lie between 0 and +5 volts. If for any reason a higher voltage is measured, *find out why — and correct it.* There will almost certainly be a soldering error, component failure, or incorrect component used, which could therefore cause extensive and expensive damage to your TNC or receiver.

demodulator tests

1. Vary the input frequency very slowly, verifying that the PLL stays in lock over a ±250 Hz range approximately. *Though the LOCK LED may go out at tuning* extremes, the UP/DOWN LEDs will be properly lit, and the meter will indicate one extreme or the other.

2. With the audio generator still connected, and with the LOCK LED lit, verify that the demodulator output signal RXdata is either high (+5 volts) or low (0 volts). Repeat several times by disconnecting the audio, and checking again.

3. Now input receiver noise instead of pure audio. The RXdata signal should jump about at random. The LOCK LED will go out, and the UP/DOWN LEDs and tuning meter may flicker.

4. Final demodulator testing requires a Phase Shift Keyed (PSK) signal. We do this when the modulator has been tested (see "audio loopback," below).

modulator tests

1. The signals TXdata, TXclock and ground must now be connected to the TNC. Switch on the TNC. PCB link LKC should also be connected.

2. *Measure the frequency* at TP4, which should be a 1200-Hz square wave. If it isn't, check to make sure you've connected link LKC correctly.

3. Examine TXdata; you should find regular data bits present — "Idling."

4. Now examine the 1200-Hz clock (TP4) and TXdata together. Verify that data transitions are seen only when the 1200-Hz clock makes a negative transition.

5. Examine the modulator output TXaudio at J3-1,2, which will have an amplitude of about 30 mV peak-to-peak. It should have a 1200-Hz clock-like appearance. Each change in TXdata will cause this clock to invert, giving rise to characteristic gaps in the trace.

audio loopback

1. The TNC should now be connected to a terminal. Temporarily link TXaudio to RXaudio (J3-1 to J3-3). Re-adjust VR1 very slightly counterclockwise towards 1200 Hz at TP1 until the LOCK LED comes on, and fine tune exactly.

2. *You should now find that you can* CONNECT to

your own callsign, and thereby talk to yourself at the terminal. Take this opportunity to study some of the waveforms — for example, the important U7 pins 6, 5, 4, 1, 2, 3, and TP3. Use TP2 as a 1200-Hz negative-going scope trigger; all signals will be synchronized to this. Observe the effect of mis-tuning by varying VR1 slightly.

3. Don't forget to return VR1 to 1500 Hz at TP1 when this test is over.

UP/DOWN tuning

1. If your receiver tunes in 100-Hz steps, you will need to set the loop bandwidth switch *(S1)* to *WIDE*. For radios with 10- or 20-Hz steps, use the NARROW position.

2. First verify that the four up-down signals work correctly. Connect a 1500-Hz audio signal to the RXaudio input; set Tune switch (S2) to OFF. Vary the frequency up and down so that the LEDs flash. Verify that there is no change on the UP/DOWN lines on J4. (J4-1, J4-2 will be low; J4-4, J4-5 will be high).

3. Throw the Tune switch to the ON position and see that the four UP/DOWN lines change in the expected manner when the frequency is varied (see circuit diagram). For example, if the UP LED comes on, J4-2 will go high and J4-5 will go low. The others will remain unchanged. Naturally, pull-ups R36-R39 must be installed to measure this. Wire link LKI may need to be connected for ICOM rigs.

4. Place the Tune switch in the OFF position and adjust the frequency to 1500 Hz. Now connect the appropriate UP/DOWN line(s) to the receiver. Turn the switch ON, vary the audio input frequency, and check that an up or a down change in displayed frequency results. Many rigs give a beep when this happens.

5. Set the switch to OFF. Connect receiver audio to the demodulator input (J3-3) as before. Tune in a steady radio carrier exactly, as indicated on the tune meter and LEDs. Set the switch ON. Carefully change the receiver frequency. If the auto-tune system is working satisfactorily, the receiver will automatically retune to the original frequency.

6. Slowly adjust the sensitivity control, VR3, clockwise. Eventually the tuning system will burst into rapid oscillation, hunting rapidly up-down-up-down . . . . Reduce the gain counterclockwise until this stops and back off a little more.

7. You will find that it pays to experiment with performance. You may also have to change the Scan control settings of your receiver. If you have an rf signal generator, a spare transmitter, or a helpful friend on the air, you can quickly optimize performance. Otherwise you must wait for a real satellite signal with changing doppler shift, such as JAS-1/FO-12 in Morse code or digital mode, or UOSAT (145.825 or 435.025 MHz, with your receiver set to CW mode).

using the satellite mailbox

Set the Tune switch to OFF and the bandwidth to WIDE. Locate the mode JD signal at 435.910 MHz, with ± doppler shift of up to 8 kHz. *Slowly* tune the receiver (in SSB/CW mode, maximum bandwidth) until the LOCK LED lights. Center the tuning, set the bandwidth to NARROW (10- to 20-Hz RX steps only), and set Tune to ON if required.

Choose one of the four uplink frequencies: 145.850, 145.870, 145.890, 145.910 MHz fm. Doppler correction is not needed. The mailbox callsign is 8J1JAS, so establish contact (TNC in COMMAND mode) with: **CONNECT 8J1JAS**. When connected, the satellite responds with the prompt: **JAS>**. You communicate with single-letter commands, which may be followed by additional specifiers — for example:

H Help (respond with commands' syntax)
F Files (list titles of ten files)
K Kill (delete specified file or files)
M Myfiles (list titles of file or files addressed to current user, presumably you)
R Read (contents of specified file or files)
W Write (message to mailbox)

When you are finished, return to TNC COMMAND mode, and DISCONNECT.

The mailbox software can be modified by the JARL command station, but the above description is essentially correct. As you can see, it's just like a terrestrial mailbox. LOGIN, and let me know you're winning!

use for terrestrial PSK packet

You can also use this modem to experiment with two-way PSK modulation for terrestrial communications (remember the audio loopback test?) Simply use the transmitter in SSB mode instead of fm. PSK offers at least 10-dB improvement over terrestrial AFSK on fm.

The local audio carrier generated this way is 1200 Hz, which is not at the center of most transmitter SSB passbands. You can change this to another frequency by first breaking link LKC and then injecting the frequency of your choice into the adjacent test point TP4. Use a single-pole, double-throw switch and you can restore normal operation at any time. The frequency needed will lie somewhere in the range 1400-1600 Hz, at a 5-volt TTL level.

follow-up support

You are invited to contact me with any technical queries about this project. You'll get a reply by return mail, provided you supply a self-addressed envelope

with 4 IRCs. I can also build and/or test your modern PCB by prior arrangement.

suppliers

For information on the availability of PCBs only, contact AMSAT-UK, London E12 5EQ, England. (Profits will help finance new Amateur satellites.) Bona fide AMSAT groups who wish to order 10 or more PCBs should contact the author directly.

Complete kits including PCBs and components are available from RADIOKIT. (Contact Carl Huether, KM1H, P.O. Box 973, Pelham, New Hampshire 03076).

Readers in the U.K. may order from AMDAT, Crofters, Harry Stoke Road, Stoke Gifford, Bristol, BS126QH, England.

references

1. J.R. Miller, G3RUH, "A PSK Telemetry Demodulator for OSCAR-10," *ham radio*, April, 1985, pages 50-62.
2. *The ARRL Handbook for the Radio Amateur*, ARRL, Newington, Connecticut, 1986, Chapter 24.

ham radio

360-degree MINIMUF propagation prediction

Simultaneous view of MUF in all directions — on your C-64

MINIMUF, a method of determining propagation modes and paths by computer, has received wide acceptance and use. Provide the sunspot number or solar flux quantity and the latitude and longitude of the two points between which communication is desired, and a 24 hour prediction of the maximum usable frequency (MUF) is obtained for that path. It's especially helpful for determining the band to use when you're interested in contacting that specific country.

However, what if you're interested in knowing where the band's open to in general? Sure, you could "Listen, listen, listen — as any successful DXer will tell you. But just now you want to get on the air, call "CQDX" and work somebody. Perhaps the whole band is filled with listeners; *somebody* has to break the ice. There's no point in rotating the beam to a non-productive direction; you have to have some knowledge as to where to point the antenna. Unless you have some other tool at your disposal, all you'll have to go on is your own experience with conditions on that band.

How many of you old-timers remember "Instantaneous Prediction of Radio Transmission Paths," the 1952 *QST* article written by the W6YG boys of Stanford University?[1] It discusses using a rotary beam to generate short transmissions of 50 WPM CW and receiving the back-scatter signals in a radar-like manner, then presenting the results on a PPI (plan position indicator). What they saw, in a 360-degree view, were the areas of the world that were open to propagation, including the first hop as well as second and third hop returns. Marvelous! They could actually see the 20-meter band openings in the morning and the different paths available during the day, and watch the band close when nighttime came. That's what we need for casual operation — a method of determining, with confidence, which direction to point our beam. There's only one problem, however; the FCC won't let us do it.

an alternate method

Dreams like that lie dormant in the mind until the state-of-the-art produces a means of accomplishing the same thing by different (and legal) means. If we accept the validity of the MINIMUF program for prediction of propagation paths — and most of us do — why not modify it to predict 360 degrees of propagation for any given hour, rather then just propagation in only one direction for 24 hours?

Suppose we scribe a circle about our QTH along great circle paths, every 10 degrees. Hold the hour constant in the MINIMUF program and have it predict the MUF for every 10 degrees of bearing. If you

0	DEG.	71.7	LAT.	HOME	LONG.+.1
10	DEG.	70.4	LAT.	62.9	LONG
20	DEG.	67	LAT.	49.7	LONG
30	DEG.	62.3	LAT.	41.5	LONG
40	DEG.	56.9	LAT.	37	LONG
50	DEG.	51.2	LAT.	34.9	LONG
60	DEG.	45.3	LAT.	34.4	LONG
70	DEG.	39.4	LAT.	35.1	LONG
80	DEG.	33.7	LAT.	36.7	LONG
90	DEG.	28.2	LAT.	39	LONG
100	DEG.	22.9	LAT.	41.8	LONG.
110	DEG.	18	LAT.	45.3	LONG.
120	DEG.	13.5	LAT.	49.2	LONG.
130	DEG.	9.5	LAT.	53.6	LONG.
140	DEG.	6.1	LAT.	58.4	LONG.
150	DEG.	3.4	LAT.	63.7	LONG.
160	DEG.	1.4	LAT.	69.2	LONG.
170	DEG.	.1	LAT.	74.9	LONG.
180	DEG.	-.3	LAT.	HOME	LONG.+.1
190	DEG.	.1	LAT.	86.5	LONG.
200	DEG.	1.3	LAT.	92.3	LONG.
210	DEG.	3.4	LAT.	97.8	LONG.
220	DEG.	6.1	LAT.	103	LONG.
230	DEG.	9.5	LAT.	107.9	LONG.
240	DEG.	13.5	LAT.	112.3	LONG.
250	DEG.	18	LAT.	116.2	LONG.
260	DEG.	22.9	LAT.	119.6	LONG.
270	DEG.	28.1	LAT.	122.5	LONG.
280	DEG.	33.7	LAT.	124.8	LONG.
290	DEG.	39.4	LAT.	126.4	LONG.
300	DEG.	45.2	LAT.	127.1	LONG.
310	DEG.	51.1	LAT.	126.6	LONG.
320	DEG.	56.9	LAT.	124.6	LONG.
330	DEG.	62.3	LAT.	120	LONG.
340	DEG.	67	LAT.	111.8	LONG.
350	DEG.	70.4	LAT.	98.7	LONG.

fig. 1. Table of bearing vs. latitude/longitude for the periphery of a 4000 km radius circle around the transmitting site at Cleveland, North Carolina.

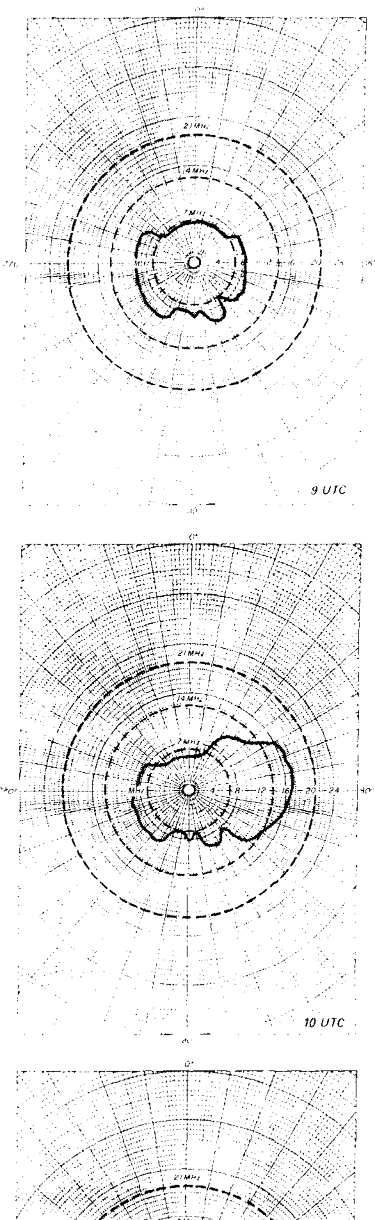
Henry G. Elwell, Jr., N4UH, Route 2, Box 20G, Cleveland, North Carolina 27013

Table 1. Program determines latitude and longitude of great circle locations 4000 km from a specified transmitting site.

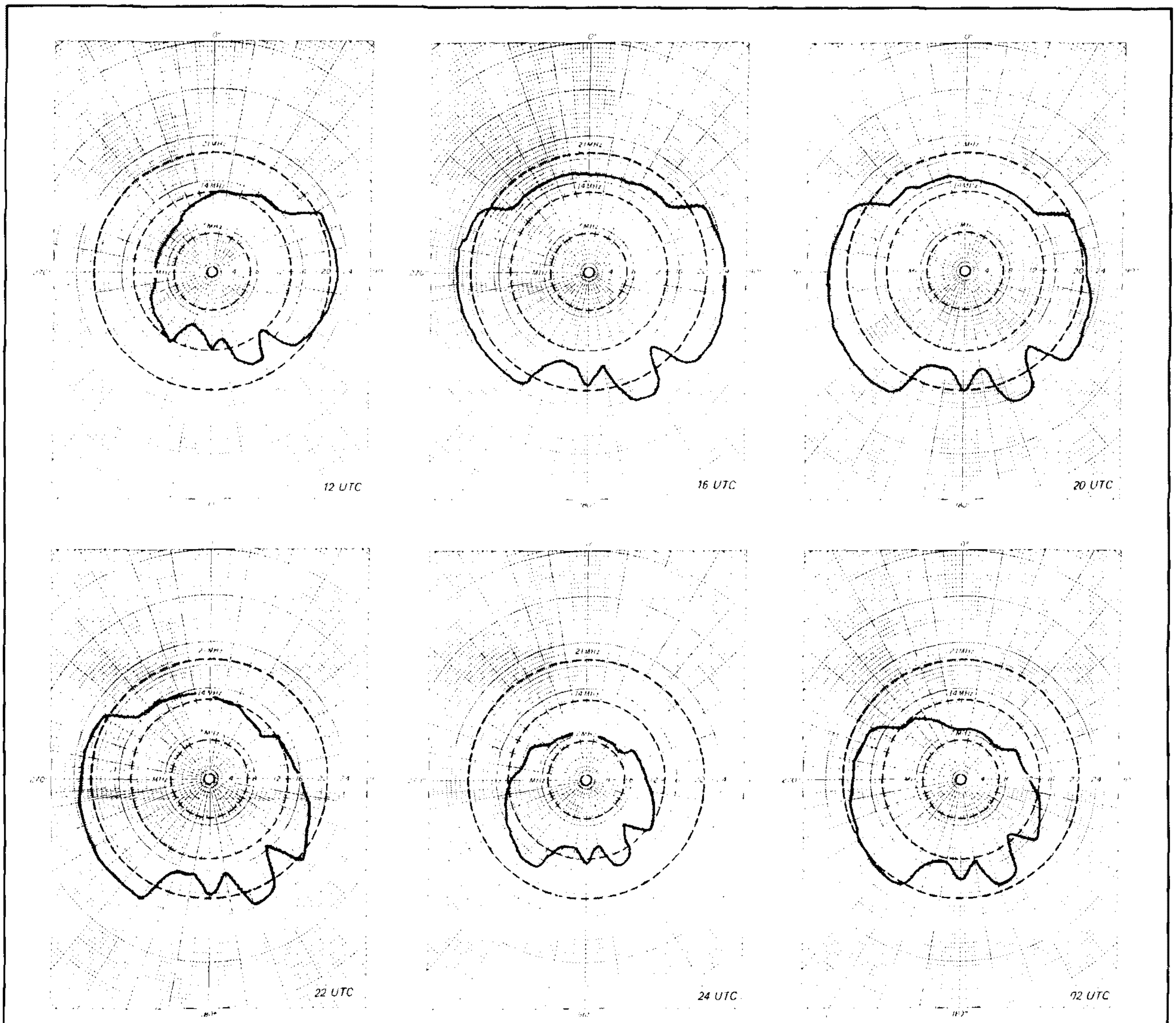
```
1 A$=CHR$(17):REM CURSOR DOWN
2 B$=CHR$(18):REM REVERSE ON
3 C$=CHR$(29):REM CURSOR RIGHT
4 D$=CHR$(147):REM CLEAR/HOME
5 PRINT D$
6 DIMH(40),P(40),T (40)
7 OPEN1,4,6:PRINT#1,CHR$(27)CHR$(69):CLOSE1
8 REM PROGRAM WRITTEN BY HENRY ELWELL N4UH DATED 7 AUGUST 1986
10 PRINTA$A$A$B$"PROGRAM TO DETERMINE THE 4000KM LATITUDE AND LONGITUDE 360 DEGR
EE":
20 PRINTB$" AROUND THE TRANSMITTING SITE TO PROVIDE PROPAGATION PREDICTIONS 360"
:
30 PRINTB$" DEGREES IN AZIMUTH FOR ANY HOUR OF THE DAY. DATA IS GIVEN EVERY ":
40 PRINT"  TEN DEGREES."
45 PRINTA$A$A$A$A$A$C$C$C$C$"PRESS SPACE BAR TO CONTINUE"
46 GETAN$:IFAN$=""THEN46
47 IFAN$=" "THEN GOTO80
50 REM THE FOLLOWING EQUATIONS MUST BE SOLVED FOR INDIVIDUAL LOCATIONS
55 REM FOR DISTANCE LAT.: L2=ARCSIN(SIN(D/60)COS(L1)COS(H)+SIN(L1)COS(D/60))
56 REM L1 IS HOME LAT.:L2 IS DIST. LAT.:D=2160 NAUT. MILES. THE ONLY VARIABLE
57 REM IS H; ALL OTHER ITEMS ARE CONSTANTS ACCORDING TO YOUR LOCATION
58 REM FOR DISTANCE LONG.: SEE LINE 59
59 REM LO2=ARCCOS(COS(D/60)-SIN(L1)SIN(L2) / COS(L1)COS(L2)) + LO1
60 REM WHERE LO2 IS THE DIST. LONG.: LO1 IS THE HOME LONG.: L2 AS COMPUTED ABOVE
70 REM ALL SIN/COS VALUES ARE CHANGED TO RADIANS FOR C-64 COMPUTATIONS.
80 PRINTA$A$:INPUT"WHAT IS YOUR HOME LATITUDE":L1
85 PRINTA$:INPUT"WHAT IS YOUR HOME LONGITUDE";LO1
87 PRINTD$A$A$A$"PLEASE WAIT FOR PRINTOUT"
90 OPEN1,4:
95 PRINT#1,"PRINTOUT OF 4000KM LATITUDE/LONGITUDE FROM 0 TO 350 DEG.; 10 DEG. ST
EPS"
97 PRINT#1:CLOSE1
100 FORH=0TO350STEP10
110 L2=.587785*COS(L1*.01745)*COS(H*.01745)+.809017*SIN(L1*.01745):REM ARCSIN
120 M=L2
130 X=ATN(M/SQR(1-M*M))*57.2957795 :REM LAT. OF DISTANT POINT
140 LETP=INT(X/0.1+.05)*.1:REM PROVIDES LAT. OF DISTANT PT. TO ONE DEC. PT.
170 REM X REPLACES L2 IN FORMULA FOR Y FOR CONVENIENCE IN ASSIGNING VARIABLES.
180 Y=(.809017-(SIN(L1*.01745)*SIN(X*.01745)))/(COS(L1*.01745)*COS(X*.01745))
190 S=(π/2-ATN(Y/SQR(1-Y*Y)))*57.296
195 IFH<180THENS=S-LO
197 IFH>180THENS=S+LO
198 T=INT(S/.1+.05)*.1
199 IFH=0THENOPEN1,4:PRINT#1,CHR$(16)"07"H:CHR$(16)"10"" DEG.":CHR$(16)"20"P;
200 IFH=0THENPRINT#1,CHR$(16)"26"" LAT.";CHR$(16)"40"" HOME LONG.+.1"
201 IFH=0THENCLOSE1:NEXTH
202 IFH=<90THENOPEN1,4;PRINT#1,CHR$(16)"06"H;CHR$(16)"09 DEG.";CHR$(16)"20"P;
203 IFH=<90THENPRINT#1,CHR$(16)"26 LAT.";CHR$(16)"40"ABS(T);
204 IFH=<90THENPRINT#1,CHR$(16)"47"" LONG":CLOSE1:NEXTH
205 IFH=180THENOPEN1,4:PRINT#1,CHR$(16)"05"H;CHR$(16)"08"" DEG.";CHR$(16)"20"P;
206 IFH=180THENPRINT#1,CHR$(16)"26"" LAT.";CHR$(16)"40"" HOME LONG.+.1"
207 IFH=180THENCLOSE1:NEXTH
208 OPEN1,4
210 PRINT#1,CHR$(16)"05"H:CHR$(16)"09"" DEG.";CHR$(16)"20"P;CHR$(16)"27""LAT.";
215 PRINT#1,CHR$(16)"40"ABS(T):CHR$(16)"47"" LONG.":CLOSE1:NEXTH
59999 END
60000 OPEN15,8,15,"S0:LAT/LONG PROP.PR":CLOSE15:SAVE"0:LAT/LONG PROP.PR",8

READY.
```

Table 2. Program provides 360-degree propagation prediction for a given hour of the day.

```
READY.
READY.
HOUR OF THE DAY
TABLE 2: PROGRAM TO PROVIDE 360 DEGREE PROPAGATION PREDICTION FOR A GIVEN
2 REM THIS PROGRAM PROVIDES A MINIMUF PROPAGTION PREDICTION FOR 360 DEGREES
3 REM FOR A SPECIFIED TIME FROM 0 TO 24 HOURS GMT
4 REM IT HAS BEEN MODIFIED BY HENRY ELWELL N4UH TO DO THAT FROM AN EARLIER
5 REM PROGRAM BY ALAN MEMLEY. KE6UY
6 REM THE REVISED PROGRAM IS DATED 7 AUGUST 1986
10 PRINT CHR$(147);"LOADING PROGRAM"
11 A$=CHR$(17):REM CURSOR DOWN
12 B$=CHR$(18):REM REVERSE ON
13 C$=CHR$(19):REM HOME
14 D$=CHR$(29):REM CURSOR RIGHT
15 E$=CHR$(145):REM CURSOR UP
16 F$=CHR$(147):REM CLEAR/HOME
17 G$=CHR$(158):REM CONTROL-YELLOW
20 FOR N = 0 TO 96
30 READX:POKE(53000+N),X
40 NEXT N
50 PRINT CHR$(147)
60 DATA 169,127,162,4,160,0,32,186
70 DATA 255,169,0,32,189,255,32,192
80 DATA 255,176,74,169,0,133,253,169
90 DATA 4,133,254,162,127,32,201,255
100 DATA 162,25,169,13,32,210,255,32
110 DATA 225,255,240,49,160,0,177,253
120 DATA 133,252,41,63,6,252,36,252,16
```



figs. 2, 3, 4: MUF propagation predictions from North Carolina at 09, 10, 11, UTC (solar flux = 70).



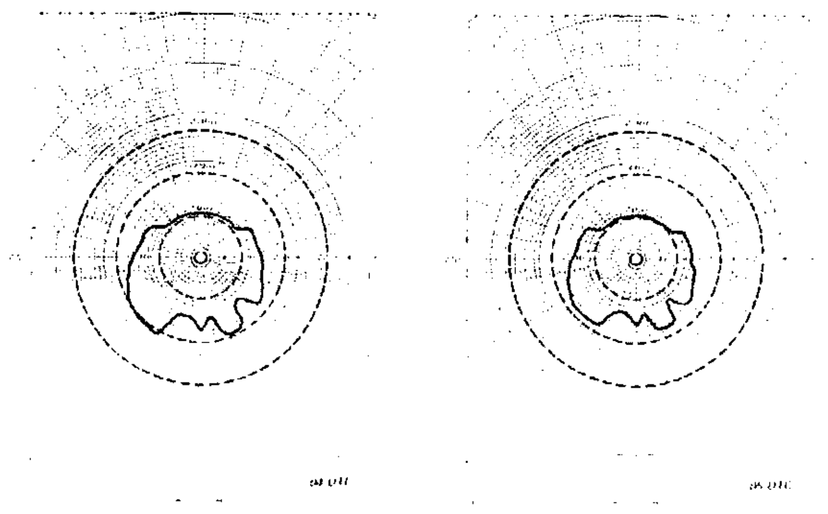
figs. 5-10: MUF predictions from North Carolina at 12, 16, 20, 22, 24, 02 UTC (solar flux = 70).

plot the MUF vs. circular degrees on polar coordinate paper, you'll have somthing very similar to the radar plots of W6YG. For any given hour you'll be able to see which bands are open or closed and in what direction you should point your beam.

One of the inevitable questions that follows this suggestion is "What distance from the home QTH should be used as a constant?" Ordinarily, you're not faced with that question in the MINIMUF program because you're concerned only with the latitude and longitude of the sending and receiving locations. True, some of the MUF programs give you the distance just for information; however, now we're going to select some arbitrary constant distance from our QTH and determine the latitude and longitude of those places every ten degrees from 0 to 360 degrees.

The following logic was used to arrive at that arbitrary distance. The W6YG boys got back-scatter from the first hop, the second hop, and even the third hop. We can get theoretical first hop by using the assumptions of the ITS[2] group who use 4000 km as the reference hop length. Four thousand km per hop length requires very low elevation angles of radiation and reception — less than about 3 degrees. Not many of us have antennas that will provide substantial enerenergy at those angles, but let's stretch it. Bob Rose, W6GKU, in his December, 1982, *QST*[3] article says the MINIMUF program is good from 250 miles to 6000 miles, so 4000 km (2500 miles) should be an acceptable number to use. We'll use it for the first hop point.

The data describing the great circle around your QTH with a radius of 4000 km must be tailored specifically to your location. You have to determine the latitude and longitude of the periphery of that circle



figs. 11, 12: MUF predictions from North Carolina at 04 and 05 UTC (solar flux = 70).

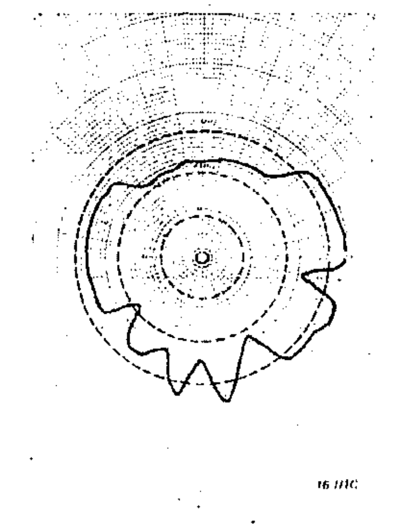


fig. 13. MUF propagation prediction from Los Angeles, California at 1600 UTC at a solar flux of 70.

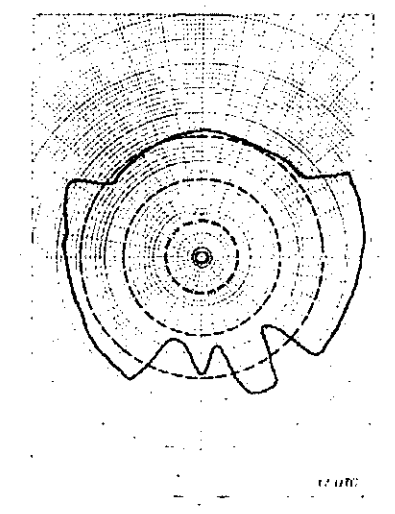


fig. 14. MUF propagation prediction from North Carolina at 1700 UTC at a solar flux of 180.

Table 2, continued.

```
130 DATA 2,9,128,112,2,9,64,32,210,255
140 DATA 200,192,40,208,230,152,24,101
150 DATA 253,133,253,144,2,230,254,202
160 DATA 208,205,169,13,32,210,255,32
170 DATA 204,255,169,127,76,195
180 REM MINIMUF FOR COMMODORE-64/ALAN MEMLEY, KE6UY
200 POKE 53280,14
210 POKE 53281,6
220 PRINT G$
230 PRINT F$
250 DIMM$(37),A$(4),M(12)
260 DATA31,28,31,30,31,30,31,31,30,31,30,31
270 FORX=1TO12:READM(X):NEXT
280 M$="JANFEBMARAPRMAYJUNJULAUGSEPOCTNOVDEC"
290 RO=π/180
300 P1=2*π
310 R1=180/π
320 PO=π/2
330 PRINT F$
340 L1=35.75:W1=80.75 :REM THE USERS HOME LATITUDE AND LONGITUDE MUST GO HERE
345 L1=L1*RO
```

Table 2, continued.

```
350 W1=W1*RO
430 GOTO600
478 REM THE BEARING, LATITUDE & LONGITUDE OF THE USER'S LOCATION MUST REPLACE
479 REM THAT SHOWN, WHICH IS FOR CLEVELAND NC ONLY
480 DATA0,71.7,80.7,10,70.4,62.9,20,67,49.7,30,62.3,41.5,40,56.9,37,50,51.2,34.9
481 DATA60,45.3,34.4,70,39.4,35.1,80,33.7,36.7,90,28.2,39,100,22.9,41.8
482 DATA110,18,45.3,120,13.5,49.2,130,9.5,53.6,140,6.1,58.4,150,3.4,63.7
483 DATA160,1.4,69.2,170,.1,74.9,180,-.3,80.7,190,.1,86.5,200,1.3,92.3
484 DATA210,3.4,97.8,220,6.1,103,230,9.5,107.9,240,13.5,112.3,250,18,116.2
485 DATA260,22.9,119.6,271,28.1,122.5,280,33.7,124.8,290,39.4,126.4,300,45.2,127
486 DATA310,51.1,126.6,320,56.9,124.6,330,62.3,120,340,67,111.8,350,70.4,98.7
487 DATA-1,0,0
488 :
500 READH,L2,W2
501 IFH=-1THENRESTORE:GOSUB3050:PRINTB$A$A$"PRESS P-PRINT:Q-QUIT:T-TRY AGAIN"
502 IFH=-1THENGOTO3000
590 GOSUB2640:GOTO865
600 PRINT:INPUT"DATE (DAY,MONTH):";D6,MO
610 IFMO<=12THEN640
620 PRINT "INVALID MONTH, MUST BE IN RANGE 1-12"
630 GOTO600
640 IFM(MO)-D6<0THEN660
650 GOTO680
660 PRINT "INVALID DAY"
670 GOTO600
680 PRINT:INPUT"SOLAR FLUX NUMBER:";SF
681 IFSF<70THENPRINT"DO NOT USE SF < 70":GOTO680
682 PRINT:INPUT"WHAT GMT DESIRED: 0 TO 23 HOURS ONLY ";TG
683 IFTG>23THENPRINT"USE HOURS 0 TO 23 ONLY":GOTO682
685 PRINT:PRINT"TURN UP AUDIO GAIN TO HEAR END OF RUN      SIGNAL"
710 S9=(-0.73+SQR((.73)^2-4*(.0008)*(65-SF)))/(2*.0008)
720 S9=INT(S9)
730 GOTO500
865 IFG=1GOTO910
866 PRINT:PRINTF$A$"HOUR="TG"Z  DAY="D6"  MONTH="MO" SF="SF
870 PRINTTAB(4)"BEARING";TAB(15)"MUF";TAB(21)"BEARING";TAB(33)"MUF"
910 L2=L2*RO
920 W2=W2*RO
940 CO=0:PRINTG$
950 T5=TG
960 CO=CO+1
970 GOSUB1140
980 J9=J9*10
990 J9=INT(J9)
1000 J9=J9/10
1010 IFCO=2THEN1050
1020 PRINT E$
1021 IFH=190THEN ED=20:GOSUB4000:PRINTTAB(22)H;TAB(32)J9:GOTO488
1022 IFH>190THENPRINTE$ TAB(22)H;TAB(32)J9:GOTO488
1030 PRINTE$ TAB(4)H;TAB(13)J9
1040 GOTO488
1050 PRINTE$E$:PRINTTAB(21)B;TAB(27)J9
1060 CO=0
1065 GOTO488
1140 REM MINIMUF 3.5
1150 K7=SIN(L1)*SIN(L2)+COS(L1)*COS(L2)*COS(W2-W1)
1160 IFK7=>-1THEN1190
1170 K7=-1
1180 GOTO1210
1190 IFK7<=1THEN1210
1200 K7=1
1210 G1=-ATN(K7/SQR(-K7*K7+1))+π/2
1220 K6=1.59*G1
1230 IFK6>=1THEN1250
1240 K6=1
1250 K5=1/K6
1260 J9=100
1270 FORK1=1/(2*K6)TO1-1/(2*K6)STEP0.9999-1/K6
1280 IFK5=1THEN1300
1290 K5=0.5
1300 P=SIN(L2)
1310 Q=COS(L2)
1320 A=(SIN(L1)-P*COS(G1))/(Q*SIN(G1))
1330 B=G1*K1
1340 C=P*COS(B)+Q*SIN(B)*A
1350 D=(COS(B)-C*P)/(Q*SQR(1-C^2))
1360 IFD>=-1THEN1390
1370 D=-1
1380 GOTO1410
1390 IFD<=1THEN1410
1400 D=1
1410 D=-ATN(D/SQR(-D*D+1))+π/2
1420 WO=W2+SGN(SIN(W1-W2))*D
1430 IFWO=>0THEN1450
1440 WO=WO+P1
1450 IFWO<P1THEN1470
1460 WO=WO-P1
1470 IFC=>-1THEN1500
1480 C=-1
1490 GOTO1520
1500 IFC<=1THEN1520
1510 C=1
1520 LO=PO-(-ATN(C/SQR(-C*C+1))+π/2)
1530 Y1=0.0172*(10+(MO-1)*30.4+D6)
1540 Y2=0.409*COS(Y1)
1550 K8=3.82*WO+12+0.13*(SIN(Y1)+1.2*SIN(2*Y1))
1560 K8=K8-12*(1+SGN(K8-24))*SGN(ABS(K8-24))
1570 IFCOS(LO+Y2)>-0.26THEN1660
```

every 10 degrees (or every 20 degrees, if you prefer) from 0 to 360 degrees. One way to do this is to solve the great circle equations for distance and bearing.

equations and calculations

Equations 1 and **2** provide a relationship between the distance (D) in nautical miles (2160 nautical miles = 4000 km), the heading (H) in degrees from your QTH (every 10 degrees), and the latitude/longitude of your location, and the first hop location.

$$D = 60 \arccos [\sin L1 \cdot \sin L2 + \cos L1 \cdot \cos L2 \cdot \cos(LO1 - LO2)] \quad (1)$$

$$H = \arccos \{[\sin L2 - \sin L1 \cos (D/60)]/[\sin (D/60) \cos L1]\} \quad (2)$$

where

L1 = latitude (your QTH)
L2 = latitude (each 4000-km hop location)
LO1 = longitude (your QTH)
LO2 = longitude (each 4000-km hop location)

The plan of attack is to solve for $L2$ in **eqn. 2** since everything else is known, then solve for $LO2$ in **eqn. 1**. Simplify by setting $\sin (D/60) = 0.587785$ and $\cos (D/60) = 0.809017$, substituting these values in **eqn. 2** and rearranging terms:

$$L2 = \arcsin [0.587785 \cos L1 \cos H + 0.809017 \sin L1] \quad (3)$$

After you enter your latitude, which is a constant, $L2$ simplies to:

$$L2 = \arcsin [(0.587785)(\text{latitude constant}) \cos H + (0.809017)(\text{different latitude constant})] \quad (4)$$

The arc sin (inverse sine) function is available on most hand calculators. Solve for $L2$, starting with 0 and continue in 10-degree steps to 350 degrees. This provides 36 latitudes around the periphery of the circle. Now all you need are the corresponding longitudes, which you can calculate from **eqn. 1**. The program in **table 1** will do all this for you automatically, but it's good to understand what you're doing. Part of a typical printout is shown in **fig. 1**.

solving for the 4000-km longitudes

By rearranging terms in **eqn. 1**, the last unknown, $LO2$ can be determined.

$$LO2 = \arccos \{[\cos(D/60) - (\sin L1)(\sin L2)]/[(\cos L1)(\cos L2)]\} \pm LO1 \quad (5)$$

At this point we now have constants for all bearings of $\cos(D/60)$, $\sin L1$, $\cos L1$, and $LO1$. $\cos L2$ can be determined for each azimuth with a hand calculator with sin/cos functions if you don't want to use the program in **table 1**. Note that there is a + or - before the $LO1$. Use the minus sign for all calculations of LO2 from 0 to 180 degrees, and a plus sign for all values from 190 to 350. When you've completed the calculations, you'll have a table of bearing vs. latitude/longitude for the periphery of a 4000-km radius circle around your transmitting site. For the 0- and 180-degree bearings, you mustn't use the same longitude as your transmitting site *even if it's the same as your transmitting site*. If they do correspond, just add 0.1 degree to your own longitude, as shown in **fig. 1**, if only to keep the mathematics under control.

MINIMUF program modifications

The updated MINIMUF program of Alan Memley, KE6UY, was modified to provide a 360-degree propagation prediction in tabular form on the screen or a printer (see **table 2**). It's necessary to provide data statements in the program for latitude and longitude crossings of the 4000-km great circles around the transmitting site, and a means for inputting time of prediction (i.e., the hour you're interested in). The basic information for month, date, solar flux, and computation of the prediction was retained. A printout for the 360-degree prediction is shown in **table 3.**

The data statements are included in **lines 480-486** of the revised program. Each data point has three numbers; bearing, latitude, and longitude. The latitude and longitude are specific to your location, and have to be calculated by hand, or by the program shown in **table 1**. Remember that commas must separate each number, and the word "DATA" must be at the the beginning of each line. If your location has three digits for latitude and/or longitude, it will be necessary to use **lines 488** and **489**. Be sure "DATA-1,0,0" is the last data item, because that ends the use of the data and restores the data pointer to the beginning of the READ information. (Basically, it helps the computer keep its bookkeeping in order.)

examples of 360-degree predictions

Let's look at several examples and see what the program tells us. We'll consider a day when the solar flux was 70. **Figures 2 through 12** show how propagation varied to different parts of the world from North Carolina from 0900 UTC through 0500 the following morning. At 0900 UTC, the maximum usable frequency (MUF) would be 10.4 MHz with propagation to all parts of the world up through 40 meters except for bearings of 310 through 50 degrees; 20 meters would not yet have opened. By 1000 UTC, 20 meters opens for the middle African countries only. By 1100 UTC, propagation is possible into Europe, all of Africa, and all except the westernmost sections of South America; the MUF into Africa is now 19.9 MHz. By 1200 UTC, the path into northern Europe, Finland (OH) is open on 20 meters and 15 meters is open to Africa, with an MUF of 21.8 MHz for Togo and countries along that bearing of 90 degrees.

Between 1600 and 2300 UTC, world-wide operation

Table 2, continued.

```
1580 K9=0
1590 G0=0
1600 M9=2.5*G1*K5
1610 IFM9<=P0THEN1630
1620 M9=P0
1630 M9=SIN(M9)
1640 M9=1+2.5*M9*SQR(M9)
1650 GOTO1910
1660 K9=(-0.26+SIN(Y2)*SIN(L0))/(COS(Y2)*COS(L0)+1.0E-3)
1670 K9=12-ATN(K9/SQR(ABS(1-K9*K9)))*7.639437
1680 T=K8-K9/2+12*(1-SGN(K8-K9/2))*SGN(ABS(K8-K9/2))
1690 T4=K8+K9/2-12*(1+SGN(K8+K9/2-24))*SGN(ABS(K8+K9/2-24))
1700 C0=ABS(COS(L0+Y2))
1710 T9=9.7*C0^9.6
1720 IFT9>0.1THEN1740
1730 T9=0.1
1740 M9=2.5*G1*K5
1750 IFM9<=P0THEN1770
1760 M9=P0
1770 M9=SIN(M9)
1780 M9=1+2.5*M9*SQR(M9)
1790 IFT4<TTHEN1820
1800 IF(T5-T)*(T4-T5)>0THEN1830
1810 GOTO1960
1820 IF(T5-T4)*(T-T5)>0THEN1960
1830 T6=T5+12*(1+SGN(T-T5))*SGN(ABS(T-T5))
1840 G9=π*(T6-T)/K9
1850 G8=π*T9/K9
1860 U=(T-T6)/T9
1870 G0=C0*(SIN(G9)+G8*(EXP(U)-COS(G9)))/(1+G8*G8)
1880 G7=C0*(G8*(EXP(-K9/T9)+1))*EXP((K9-24)/2)/(1+G8*G8)
1890 IFG0=>G7THEN1910
1900 G0=G7
1910 G2=(1+S9/250)*M9*SQR(6+58*SQR(G0))
1920 G2=G2*(1-0.1*EXP((K9-24)/3))
1930 G2=G2*(1+(1-SGN(L1)*SGN(L2))*0.1)
1940 G2=G2*(1-0.1*(1+SGN(ABS(SIN(L0))-COS(L0))))
1950 GOTO2020
1960 T6=T5+12*(1+SGN(T4-T5))*SGN(ABS(T4-T5))
1970 G8=π*T9/K9
1980 U=(T4-T6)/2
1990 U1=-K9/T9
2000 G0=C0*(G8*(EXP(U1)+1))*EXP(U)/(1+G8*G8)
2010 GOTO1910
2020 IFG2>J9THEN2040
2030 J9=G2
2040 NEXTK1
2050 J9=.93*J9
2060 G=1:RETURN
2640 RA=3956.75
2650 X7=RA*SIN((90-X1)*π/180)*COS(Y1*π/180)
2660 Y7=RA*SIN((90-X1)*π/180)*SIN(Y1*π/180)
2670 Z7=RA*COS((90-X1)*π/180)
2680 DE=((X7^2)+(Y7^2)+(Z7^2))^.5
2690 CA=X7/DE:CB=Y7/DE:CC=Z7/DE
2700 X8=RA*SIN((90-X2)*π/180)*COS(Y2*π/180)
2710 Y8=RA*SIN((90-X2)*π/180)*SIN(Y2*π/180)
2720 Z8=RA*COS((90-X2)*π/180)
2730 DG=((X8^2)+(Y8^2)+(Z8^2))^.5
2740 CD=X8/DG:CE=Y8/DG:CF=Z8/DG
2750 CT=((X7*X8)+(Y7*Y8)+(Z7*Z8))/(DG*DE)
2760 IFCT=0THENCT=.00000000001
2770 DI=((RA^2)+(RA^2)-2*RA*RA*CT)^.5
2780 IFDI>5656.85425THENGOTO2810
2790 SI=(1-(CT^2))^.5
2800 TA=SI/CT:T=ATN(TA)*180/π:GOTO2830
2810 SI=-1*(1-(CT^2))^.5
2820 TA=SI/CT:T=180-ATN(TA)*180/π
2830 DX=69.055*T:DX=INT(DX)
2840 RETURN
3000 GETAN$:IFAN$=""THEN3000
3010 IFAN$="P"GOTO3200
3020 IFAN$="Q"THENPRINTF$A$A$D$D$D$"ENJOY YOUR RADIO!":END
3030 IFAN$="T"THENPRINTF$A$A$A$A$"PLACE CURSOR OVER RUN AND PRESS RETURN"
3031 IFAN$="T"THENGOTO3040
3035 GOTO3000
3040 PRINTE$E$E$E$E$"RUN":END
3050 : REM TONE TO TELL WHEN SCREEN PRINT COMPLETE
3052 FOR AC=54272TO54296:POKEAC.0:NEXT
3054 POKE54296.15
3056 POKE54277.0
3058 POKE 54278.248
3060 POKE54273.35:POKE54272.134
3062 POKE54276,17
3064 FORT=1 TO 1000 :NEXT
3066 POKE54276,16:RETURN
3199 REM SCREEN DUMP
3200 OPEN3,3:OPEN4,4:PRINTC$:FORI=1TO1000:GET#3,A$:PRINT#4,A$;:NEXT:CLOSE3
3210 CLOSE4
3220 END
4000 FORI=1TOED:
4010 PRINTE$;
4015 NEXTI
4020 RETURN
60000 OPEN15,8,15,"S0:360 DEG MUF":CLOSE15:SAVE"0:360 DEG MUF",8

READY.
```

Table 3. 360-degree MINIMUF prediction for Cleveland, North Carolina at a solar flux of 70.

BEARING	MUF	BEARING	MUF
0	16.7	190	15.8
10	16.9	200	15.7
20	17.2	210	22
30	17.5	220	21.9
40	17.9	230	22
50	18.2	240	22
60	23.2	250	22
70	23.6	260	22
80	23.9	271	21.9
90	24.2	280	21.7
100	24.4	290	21.4
110	24.5	300	21.2
120	24.4	310	16.7
130	24.2	320	16.6
140	17	330	16.5
150	23.5	340	16.5
160	23.1	350	16.6
170	16.2		
180	19.2		

is possible in all directions on 20 meters, with the MUF extending as high as 25 MHz on bearings into Pitcairn Island at 230 degrees, although the heavily populated areas of middle Europe had dropped out by 2200 UTC. At 0000 UTC, the next day, the prediction says 20-meter propagation is possible to South America and west up through Hawaii. A possible 15-meter capability is indicated into the southwest.

By 0200 UTC, 4000 km propagation is still possible on 20 meters for South America and the South Pacific. The band is still open at 0400 UTC, with an MUF of 14.5 in the 210-220 degree bearing for some possible Central American stations. Twenty meters is dead at 0500 UTC, with an MUF of 13.3 MHz. To provide a comparison with North Carolina and Los Angeles, California, a prediction was run for 1600 UTC on the same day with a solar flux of 70 for Los Angeles; see **fig. 13**. California is three hours earlier than North Carolina, but it still shows world-wide propagation possibilities on 20 meters, with good openings into Africa and South America on 15 meters.

Just for fun, a prediction for the 21st of June — in a year when the solar flux was 180 — was run (**fig. 14**). As expected, practically the whole world is open on the 10-meter band at 1700 UTC. (I believe the model used for the prediction is quite conservative, since it would appear that the MUF should be higher than 35.9 MHz with such a high solar flux.)

This type of presentation — i.e., 360 degrees — brought out what may be an anomaly in the prediction model. It appears that the 140-degree prediction for North Carolina is always significantly lower than the 130- and 150-degree bearing. Also, the 170- through 200-degree predictions seem to be lower than adjacent bearings. I'd be interested in hearing from any reader who could explain this.

a word of caution

It's important to remember that hops greater than the 4000-km prediction may not be possible because of propagation conditions at the far end. However, this modified program can suggest possible contacts. It's also good to keep in mind that the predicted openings may provide the long path for distant points even when no short path conditions are indicated.

The next step, should anyone want to continue this work, would be to provide the code for a graphic presentation such as the one shown in **figs. 2** through **14**. It should be an easy task to combine the point-to-point prediction with the 360-degree prediction, since the basic MINIMUF program is used by both methods.

references

1. "Instantaneous Prediction of Radio Transmission Paths," *QST*, March, 1952, page 11.
2. Institute for Telecommunication Sciences, *Telecommunications Research and Engineering Report 13*, Ionospheric Predictions, Volume 1.
3. Robert R. Rose, K6GKU, "MINIMUF: A Simplified MUF-Prediction Program for Microcomputers," *QST*, December, 1982, page 30.

ham radio

C64/128 routines
determine optimum
Class B or C operation

linear design by computer

A few years ago *ham radio* published an article of mine on low-cost linear design and construction.[1] Judging from the number of letters and phone calls I've received, the techniques have been widely used. It seems that linear construction is second only to antennas as an Amateur activity.

Recently, while doing some study on a new linear to fit our new regulations, I went through these design steps a number of times. Finally, I decided that this was a lot of unnecessary work, so I took time to reduce the process to a computer routine.

The core of the computer routines are the tables and relations given in the booklet, *RCA Transmitting Tubes, Technical Manual TT-5.* (My copy is dated October, 1962.) As far as I know, the book is out of print, but copies are occasionally found at hamfests. It isn't necessary to have the book to use the program — just refer to the manufacturer's literature for design data on the types of tubes you plan to use.

As written, the program listed in **table 1** is for the Commodore 64/128. However, only routine constructions are used, so only minor changes would be needed to make it run on other computers.

Lines below **500** are introductory. **Line 180** sets up a function for output formatting. The amplifier design goals are established in **lines 500-990**. The last lines allow either acceptance of the "preliminary" design developed at that point or redesign. On the C-64, it isn't necessary to re-enter all values; you need enter only the ones you wish to change. Other computers may require complete re-entry.

The basic design parameter chosen is power output, which seems to be the most common goal. The next two inputs are the number of tubes to use and the operating class. The program assumes that the tubes will be in parallel, as is universal in today's hf designs. The program also assumes that designs will be either Class B, with a 180-degree conduction angle, or Class C at 140 degrees. For convenience, a set of values for 100-degree angle is listed in the REM statement at **line 550**. These may be substituted for the 140-degree ones if desired, or a third mode programmed. Although an increase in output will be obtained, harmonic content will increase, so this step is not recommended.

Lines 530-550 introduce some "K" values, and more are used later. These are the core of the RCA design technique, and are tabulated in the RCA booklet. They are derived from the way parameters of truncated sine waves behave. Clipped sine waves are generated by the non-linear relation between driving grid voltage and resulting plate current pulses. (See any good book on vacuum tube amplifiers if you're interested in details.) For calculation, most of the K-factors are used as tabulated; however, one is calculated from a least-squares relation.

The values of plate and screen voltage and plate dissipation are entered in **lines 570-600**. A *minus* screen voltage is used to indicate a triode. Note that the plate dissipation is specifically a design parameter, but that there is no built-in check for screen or grid dissipation; these are calculated and output later, to check against tube specification values.

It is usually best to operate near the upper limit of

R. P. Haviland, W4MB, 1035 Green Acres Circle N., Daytona Beach, Florida 32019

Table 1. Linear amplifier design program for the C64.

```
100 PRINT"" ****************************************"
110 PRINT"  *            VACUUM TUBE             *"
120 PRINT"  *  HIGH POWER RF AMPLIFIER DESIGN    *"
130 PRINT"  *  REFERENCE RCA TECH MANUAL TT-5    *"
140 PRINT"  *   HAM RADIO, PAGE 12, DEC.1982     *"
150 PRINT"  *            FEBRUARY 1986           *"
160 PRINT"  *         R.P.HAVILAND, W4MB         *"
170 PRINT"  ****************************************"
180 DEF FNP(X)=INT(X*10+.5)/10
200 PRINT" THIS PROGRAM AIDS DESIGN OF HIGH POWER   RF AMPLIFIERS, CLASS B AND C
"
210 PRINT"   BEST DESIGN REQUIRES INPUT FROM           TUBE DATA CURVES"
220 PRINT"     APPROXIMATIONS ARE SUPPLIED IF            CURVE DATA IS NOT AVAIL
230 PRINT
500 INPUT"ENTER DESIGN POWER OUTPUT,WATTS";PO
510 INPUT" ENTER NUMBER OF TUBES TO USE";NV:PT=PO/NV
520 INPUT"  ENTER MODE, B=CLASS B,C=CLASS C";MO$
530 IF MO$="B" THEN K2=.785:GOTO570:REM 180 DEG.
540 IF MO$="C" THEN K2=.862:GOTO570:REM 140 DEGREE
550 REM FOR 100 DEG CONDUCTION, K2=.927,K3=1.8,K4=2.8,K5=1.45
560 GOTO 520
570 INPUT"   ENTER PLATE VOLTAGE",EB
580 INPUT"ENTER SCREEN VOLTAGE, -1= A TRIODE";SV
600 INPUT"ENTER RATED TUBE DISSIPATION,WATTS";DI
610 EN=.1*EB:EM=EN:REM TRIAL
620 IP=PT/(K2*(EB-EM))
630 K1=3.14: IF MO$="C" THEN K1=4
640 IM=K1*IP
650 PRINT
700 PRINT"INPUT TUBE DATA-PLATE VOLTAGE AT KNEE OF IP=";INT(1000*IM);"MA. CURVE"
710 PRINT"  OR ENTER ZERO FOR AN APPROXIMATION"
720 INPUT EM: IF EM=0 THEN 740
730 IF ABS(EM-EN) > .01*EM THEN EN=EM:PRINT" ANOTHER TRIAL NEEDED":GOTO620
740 PI=EB*IP*NV
750 PD=(PI-PO)/NV
760 PRINT
800 PRINT"REQUIRED INPUT IS";FNP(PI);"WATTS"
810 PRINT" DISSIPATION PER TUBE IS";FNP(PD);"WATTS
820 PRINT"  WITH PLATE CURRENT =";FNP(1000*IP);"MILLIAMPS"
830 PRINT"   TOTAL CURRENT, AMPS=";FNP(NV*IP)
840 DC=PD/DI
850 PRINT
900 PRINT" DESIGN WILL BE SUITABLE FOR"
910 IF DC<.94 THEN PRINT"    AM VOICE"
920 IF DC<1 THEN PRINT"    FM-TELETYPE"
930 IF DC<1.4 THEN PRINT"    CW"
940 IF MO$="B" AND DC<1.83 THEN PRINT"    PROCESSED SSB"
950 IF MO$="B" AND DC<2.5 THEN PRINT"    NORMAL SSB"
960 IF DC>2.5 THEN PRINT"    LOW DUTY CYCLE OR PULSE ONLY"
970 IF DC>1 THEN PRINT"    USE LOW TUNE-UP POWER"
980 PRINT:INPUT"ENTER A=ACCEPT OR R=REJECT VALUES";T$
990 PRINT:IF T$="R" THEN 500
1000 PRINT"INPUT TUBE DATA, OR 0 IF NOT AVAILABLE"
1010 PRINT"FOR APPROXIMATE DISSAPATIONS AND DRIVE"
1020 INPUT"ENTER GRID VOLTAGE AT I-PLATE MAX";V1:IF V1=0 THEN V1=.1*EB
1030 INPUT"ENTER IG1 (AMPS) AT I-PLATE MAX",J1:IF J1=0 THEN J1=IM
1040 INPUT"ENTER GRID OR SCREEN MU-FACTOR";MU
1050 IF MU=0 THEN PRINT"SET BIAS AND DRIVE BY TEST" GOTO 1260
1060 IF MU=0 THEN PRINT"SET BIAS AND DRIVE BY TEST":GOTO 1260
1070 PRINT
1100 K3=0:K4=1
1110 IF MO$="C" THEN K3=.52 K4=1.52
1120 EX=SV:EY=0
1130 IF SV<0 THEN EX=EB:EY=EM:K4=1
1140 VG=-K3*(V1+EY/MU)-K4*EX/MU
1150 VD=-VG+V1
1160 PRINT"PEAK RF GRID VOLTAGE=";FNP(VD)
1170 PRINT" GRID BIAS VOLTAGE=";FNP(VG)
1180 IF VD=0 THEN 1290
1200 RA=ABS(VG/VD)
1210 K6=11.82-35.59*RA+43.06*RA*RA
1220 IC=J1/K6
1230 PG=ABS(.9*VD*IC)*NV
1240 PRINT"  GRID CURRENT PER TUBE, MA.=",FNP(1000*IC)
1250 PRINT"    TOTAL DRIVE POWER, WATTS=";FNP(PG) PRINT"  PLUS CIRCUIT LOSSES"
1260 PRINT"TYPICAL STAGE POWER GAIN=",
1270 IF SV=-1 THEN PRINT" 10"
1280 IF SV>0   THEN PRINT" 20"
1290 PRINT
1300 IF SV<0 THEN 1500
1310 INPUT"ENTER IG2 (AMPS) AT IP KNEE";J2 IF J2=0 THEN J2=.1*IM
1320 K5=.25:IF MO$="C" THEN K5=.2
1330 I2=K5*J2
1340 P2=SV*I2 PA=J2*V1*K5/2 IF P2<PA THEN P2=PA
1350 PRINT"SCREEN CURRENT, MA.=",FNP(1000*I2)
1360 PRINT" SCREEN DISSIPATION, WATTS=";FNP(P2)
1370 PRINT
1500 ES=EB-EM
1510 IE=2*K2*EB*IP/ES
1520 K7=2:IF MO$="B" THEN K6=1.57
1530 ZL=ES/K7/IP/NV
1540 PRINT
1600 INPUT"CATHODE DRIVE CONDITIONS, Y/N":T$ PRINT
1610 IFT$="N" THEN 2000
1620 PF=ABS(VD)*IE/2
1630 ZK=VD/(IE+1.5*IC)
```

```
1640 PRINT"TOTAL POWER, EXCITER TO LOAD, WATTS=",FNP(PP*NV)
1650 PRINT"  TOTAL EXCITER POWER, WATTS=",FNP(NV*(PP+PG))
1660 PRINT"     PLUS CIRCUIT LOSS"
1670 PRINT"    TOTAL OUTPUT, WATTS=",INT(PO+PP*NV)
1680 PRINT:PRINT"DRIVE IMPEDANCE=",INT(ZI):PRINT
2000 PRINT"TANK CIRCUIT DESIGN":PRINT
2010 INPUT"ENTER TUBE OUTPUT CAPACITY, PF",CT
2020 INPUT" ENTER C-MIN+C-STRAY, PF",I
2030 CT=CT*NV+I
2040 INPUT"  ENTER MAXIMUM FREQUENCY, MHZ",FH
2050 INPUT"   ENTER LOWEST FREQUENCY, MHZ",FL
2060 PRINT:PRINT"LOAD IMPEDANCE SHOULD BE",INT(ZL),"OHMS"
2200 XH=1E6/(2*π*FH*CT)
2210 QM=ZL/XH
2220 PRINT" TANK Q AT F-MAX="INT(QM+.5)
2230 IF QM>15 THEN PRINT:PRINT" Q IS EXCESSIVE-SEE HAM RADIO REFERENCE"
2240 X1=ZL/12
2250 X2=50/SQR((50/ZL)*145-1)
2260 XL=ZL*(12+50/X2)/145
2270 C1=1E6/(2*π*FL*X1)
2280 C2=1E6/(2*π*FL*X2)
2290 L=XL/(2*π*FL)
2300 PRINT:PRINT" TUNING CAPACITY AT ",FL,"MHZ =",FNP(C1)," PF"
2310 PRINT"  AND 50 OHM LOAD CAPACITANCE, PF=",FNP(C2)
2320 PRINT" MAXIMUM COIL INDUCTANCE,UH=",FNP(L)
2400 INPUT"ENTER COIL DIAMETER, INCHES",CD
2410 INPUT" ENTER COIL LENGTH, INCHES",CL
2420 CN=SQR(L*(18*CD+40*CL))/CD
2430 PRINT"  COIL TURNS=",FNP(CN)
2440 PRINT"    TURNS/INCH=",FNP(CN/CL)
2450 PRINT" TAP COIL FOR HIGHER FREQUENCY BANDS"
2460 INPUT"  ENTER ADDED BAND FREQUENY OR 0",NF:IF NF=0 THEN PRINT:GOTO 2500
2470 TP=CN*FL/NF
2480 PRINT"TAP AT ",FNP(TP)," TURNS APPROX." IF QM>15 THEN PRINT"BUT SEE HR REFE
RENCE"
2490 GOTO 2460
2500 IF T$<>"Y" THEN 2600
2510 FC=1.5*FH:MP=ZI/50
2520 C3=1E6/(50*2*π*FC)
2530 C4=C3/MP
2540 LK=(1+MP)*(50/2/π/FC
2550 PRINT"FOR PI FILTER-GROUNDED GRID INPUT"
2560 PRINT" C-IN=",FNP(C3)," PF"
2570 PRINT" C-CATHODE=",FNP(C4)," PF"
2580 PRINT" SERIES INDUCTANCE=",FNP(LK), "UH"
2600 PRINT:PRINT"ENTER POWER SUPPLY TYPE"
2610 PRINT" 1=FULL WAVE"
2620 PRINT" 2=BRIDGE"
2630 PRINT" 3=FULL WAVE DOUBLER"
2640 INPUT PT
2650 TS=EB/1.3
2660 IF PT=3 THEN TS=EB/2.6
2670 PRINT"TRANSFORMER VOLTAGE=",INT(TS)
2680 IF PT=1 THEN PRINT"EACH SIDE OF CENTER"
2690 FC=30000*NV*IP/EB
2700 IF PT=3 THEN FC=FC*S
2710 PRINT" FILTER CAPACITANCE, MFD =";INT(FC)
3000 PRINT:PRINT"ENTER N=NEW CONDITIONS"
3010 PRINT"       R=REVISE CONDITIONS"
3020 PRINT"       P=REVISE POWER SUPPLY"
3030 PRINT"       Q=QUIT"
3040 INPUT T$
3050 IF T$="N" THEN RUN
3060 IF T$="R" THEN 500
3070 IF T$="P" THEN 2600
3080 STOP

READY.
```


✓ 234

Table 2. Results of a typical run of the program, using approximations (*indicates an input).

```
Example Tube Type- 4-1000A

* Power output- 1600 watts
* One tube
* Class B
* Plate- 3500 volts
* Screen- 0 volts= GG
* Dissipation- 1000 watts
Plate current- 2031 ma peak
Ep min- 0= approximation
Plate input- 2264.7 watts
Dissipation- 664.7 watts
Plate current- 647.1 ma average
Suitable all modes
* Grid, screen current-0= approximation
* MU factor- 7
RF grid voltage- 350
Bias- 0
Grid current- 171.9 ma
Grid drive- 54.1 watts
Stage gain- 20
Screen dissipation- 8.9 watts
Exciterr to load- 177 watts
Total drive- 239.1 watts + losses
Total output- 1777 watts
Z-drive- 274 ohms
* Tube C-out- 7.1 pf
* C-stray- 15 pf
* F max, min- 30, 3.5 mhz
Plate impedance- 2709 ohms
Q max- 12
Max C tune- 201.8 pf
Max C load- 1179 pf
Max L- 11.3 uh
* Coil 4" dia, 5" long
Turns- 13.2
* 14 mhz tap- 3.5 (approx)
Cathode Filter
 C-in 70.7 pf
 C-out 12.9 pf
 L  1.1 uh
* Bridge Rectifier
Transformer- 2692 volts rms
Filter 5 mf
```

plate voltage if maximum output is needed. In the low duty-cycle services, it may be desirable to exceed the usual oscillator-amplifier rating. Up to about 1.5 times the plate modulated amplifier rating seems to work well, with little loss of service life.

Line 700 calls for the plate voltage at estimated maximum plate current, which is the intersection of the load line and the plate current curve for the peak instantaneous grid voltage. Since this is not yet determined, several trials will be necessary to select a reasonable value. Maximum output is usually the design goal in the Amateur Service. For this, use the plate current at the knee of the curve for the maximum grid voltage shown on the tube curves, then follow the instructions. The program allows this important step to be replaced by an approximation, but this is only for the initial design.

After this step, accumulated design values are output for checking. This includes power input, tube dissipation, and current. The type of service the design values are suited to is output; this is based on typical duty factors. Note that these assume good cooling. The design values can be accepted, or new ones calculated.

Program lines **1000-1680** calculate and output further design data based on curve data. One input is the tube amplification factor, which is the screen factor for tetrodes. Typical values are 4-9 for tetrodes and 20-150 for triodes. Grid and screen dissipation values must be checked against rated values. A small amount of instantaneous overload is allowable for the low duty-cycle services, but there is some risk of shortening tube life if rated values are exceeded. Sometimes it is best to increase plate voltage to reduce drive requirements.

This section also allows estimation of the drive impedance for grounded grid amplifiers. Drive requirements and power fed to the load are calculated.

The section from **lines 2000-2490** relates to the plate tank circuit. A simple tapped coil pi-section tank is assumed. Values are calculated for the lowest frequency. Tap points for higher bands are developed by an approximation. The actual tap points should be determined by a test for maximum output. The reason for this is the difficulty of estimating inductance and stray capacitance of the band switch and leads.

The tank design assumes a Q of 10 at the lowest frequency. A flag is printed if the Q at the highest band exceeds 15, as a result of high tube plus stray capacitance. (See reference 1 for a means of avoiding this by designing the circuit as a L-PI network).

Lines 2500-2580 give design data for a PI network grounded grid excitation input circuit. This assumes cutoff at 1.5 times the highest operating frequency. In principle, this design is not as good as a separate tank circuit for each band ($Q = 2$, approximately), but it is far simpler and has presented no problems in years of use.

Lines 2600-2710 give power supply parameters for three types of rectifiers. (When working with surplus transformers, it may be necessary to base the design on a particular transformer voltage rather than on plate voltage.) Remaining lines relate to re-runs.

Table 2 shows results of a typical run of the program.

references

1. Robert P. Haviland, W4MB, "Low-Cost Linear Design and Construction," *ham radio*, December, 1982, p. 12.

ham radio

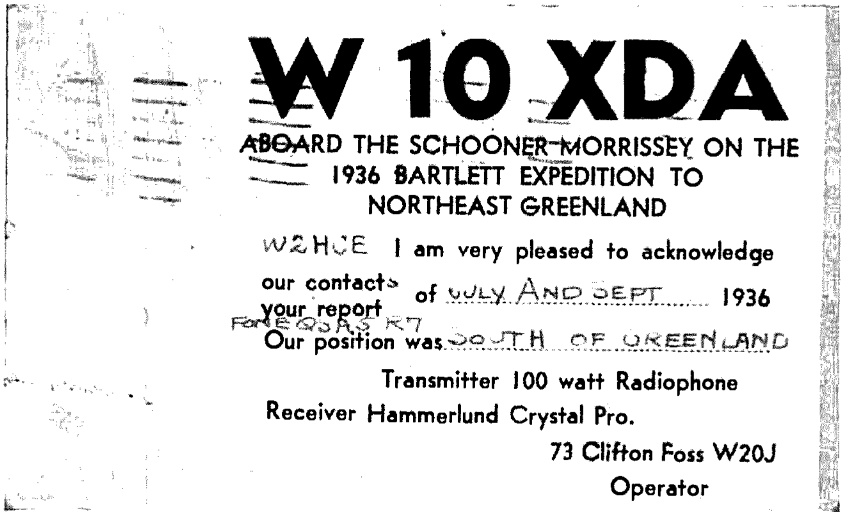
ham radio TECHNIQUES

Bill Orr W6SAI

ever work a W10?

Prefix hunters should snap to attention at this one! But the bad news is that W10 prefixes were consigned to the scrap-heap shortly after World War II. The W10 prefix was a catch-all for mobile, experimental stations, and many of the calls were issued to expeditions who wished to keep in touch with home via Amateur Radio.

The most famous of these unusual calls was W10XDA, the ham-band call of the schooner *Effie M. Morrissey*, under Captain Robert Bartlett, a noted Arctic explorer. The *Morrissey* made numerous trips to Northern Greenland from 1936 through 1939, and the call was well-known on the 20-meter phone band.



W 10 XDA

ABOARD THE SCHOONER MORRISSEY ON THE 1936 BARTLETT EXPEDITION TO NORTHEAST GREENLAND

W2HCE I am very pleased to acknowledge our contacts of JULY AND SEPT 1936

your report For E QSA5 R7

Our position was SOUTH OF GREENLAND

Transmitter 100 watt Radiophone

Receiver Hammerlund Crystal Pro.

73 Clifton Foss W2OJ

Operator

W10 prefix was used by mobile, expedition and experimental stations.

The adventures of the *Morrissey* and Captain Bob had slipped to the back of my mind until I read an article about New Bedford, Massachusetts in *Yankee*.[1] Almost as an afterthought, the author mentioned the *Ernestina*, an 1894 schooner presently being restored at anchor in New Bedford. The author further stated that this was formerly the famous *Morrissey*, which had not only explored the Arctic, but also served as an immigrant packet in the 1890s.

So Amateurs wishing to review some of their own history might visit this famous schooner, which once bore the proud call sign W10XDA that started a hundred pile-ups on 20 meters, so many decades ago.

more about the super-cathode driven amplifier

Judging from mail received, there is considerable interest in the cathode driven circuit and the super-cathode driven offspring. Here are some specifics on the 4-400A as used in that circuit (see **fig. 1**).

In conventional grounded grid service, a single 4-400A can run at 1 kW PEP input, requiring about 40 watts PEP drive power. While many Amateurs have operated one or two tubes in this fashion, with both grids grounded, the margin of error for excessive grid dissipation is small. In addition, grid and screen currents are quite high.

When the 4-400A is run in super-cathode driven service, grid and screen dissipation drop, along with the corresponding currents, and grid drive power rises. The circuit for a single 4-400A, in fact, may be adjusted to "soak up" the drive power of most modern hf SSB exciters, which usually run 100 to 130 watts output.

An experimental amplifier was constructed using a single 4-400A; the operating characteristics are summarized in **table 1**. Note the unusually high value of cathode input impedance.

The amount of drive required by the amplifier is determined by placement of the cathode tap. The nearer the tap is to the filament end of the choke, the greater the required drive. When the tap is at the "ground" end of the choke, the tube operates in the conventional grounded grid mode. For the typical 100-watt output exciter, the tap is placed about one-third of the distance down the choke from the tube end.

It is necessary to use a blocking capacitor between the tap point on the choke and the grid in order to prevent the ac filament voltage from reaching the grid. The dc grid return is then completed through a small rf choke.

In any case, total grid current (sum of grid and screen currents) should be limited to about 150 mA.

the tapped filament choke

A handy filament choke can be made by winding two equal lengths of wire on a ferrite rod. One wire is Formvar (or enamel) insulated, the other is

Table 1. Suggested operating parameters for 4-400A in Super cathode driven service.

Plate voltage (key down)	3000 VDC
Plate current (carrier insertion)	333 mA
Power input (peak)	1000 W
Power output (measured)	600 W
Power drive	100-125 W
Plate load impedance	4100 ohms
Cathode input impedance	420 ohms

Drive power depends on tap setting on filament choke.

Note: The above data has been determined experimentally by Bill Orr, W6SAI, and does not represent the opinion of Varian/EIMAC.

bare, tinned. The tinned wire allows the experimenter to tap along the choke; the Formvar insulation on the other wire prevents the solder from flowing onto the adjacent turns and causing a short circuit.

The super-cathode driven amplifier tunes up in the conventional way. Plate voltage is applied and plate circuit resonance is established at a low drive level. Drive power should be checked with an in-line wattmeter in the coax lead to the amplifier. The tap is adjusted on the filament choke for maximum output when the exciter is running at the desired input level.

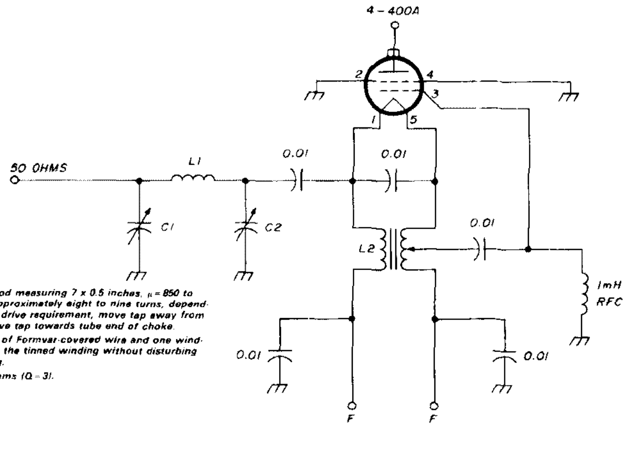
Warning! Keep your hands out of the amplifier when the high voltage is on. After turning off the power supply, short the B-plus lead to ground in the amplifier with a plastic-handle screwdriver or other insulated tool to make sure the filter capacitors are discharged before you do any work on the amplifier. *High voltage is deadly!*

"stealth" technology —in police radar!

We've all read about the new stealth technology, by which a fighter plane is rendered "invisible" to radar. Well, science has taken another gigantic step. The September issue of *Defense Electronics* tells about an advertisement in a leading auto magazine offering motorists the opportunity to elude police radar for only $17.95. According to the ad, the technique involved is the same as the one used to make U.S. aircraft invisible to enemy radar. A breakthrough in low-cost countermeasures? No. Just an aerosol can of silicone spray unconditionally guaranteed to deflect radar waves!

The editor of *Defense Electronics* tried telephoning the company, but the line was always busy. . . no doubt Washington was calling to learn about the benefits of this momentous idea.

Reminds me of the time I saw a big crowd of curious onlookers outside a shop in the golden days of CB radio. What could be causing the commotion? I stopped and found a fellow selling "SWR grease" from the back of his truck. Smear the grease on your mobile whip antenna, he told the onlookers, and your SWR will instantly drop to 1:1. I should have bought some and tried it on my three-element beam, but I had to finish paying off my purchase of the Brooklyn Bridge first.



L2 = 20 bifilar turns No. 14 on ferrite rod measuring 7 x 0.5 inches, μ = 850 to 950 (Amidon). Tap down from tube approximately eight to nine turns, depending upon exciter output. To decrease drive requirement, move tap away from top (tube end). To increase drive, move tap towards tube end of choke.

I wound my choke with one winding of Formvar-covered wire and one winding of tinned wire. It was easy to tap the tinned winding without disturbing the adjacent, Formvar-coated winding.

Tuned input network to match 420 ohms (Q = 3).

f(MHz)	C_1(pF)	C_2(pF)	L_1(μH)
3.5	302	192	6.5
7.0	150	96	3.3
14.0	75	48	1.6
21.0	50	32	1.1
28.0	37	24	0.8

fig. 1. Super-cathode driven 4-400A circuit uses adjustable filament choke tap position to vary input drive level to be used.

how good is a rubber ducky?

The Lee DeForest Club (California) decided to make some meaningful measurements on typical handheld units in the 2-meter band. Willie Sayer, WA6BAN, sent along the results of those tests, along with a description of the setup. The field strength measured at a distance was converted into antenna efficiency, taking into account the power output of the handheld. The winner of the event was KG6NL, who was using an AEA "Hot Rod" antenna, which exhibited an *efficiency* of about 57 percent. WA6BAN's handheld, with a conventional "Rubber Ducky" produced a reading that indicated efficiency of only 7 percent. Other handhelds with comparable antennas were in the same ballpark.

rf light bulbs — a continuing problem

Light bulbs that actually generate RFI, causing interference to nearby radios, are on the market in quantity.

Sold under various brand names — GE's "Miser Maxi-light" and North American Philips' "SL-8" are two — they use less wattage to provide light and presumably last longer than conventional bulbs. Their threat to a-m radio (and possibly 160- and 80-meter Amateur operation) is in the way they generate light.

The rf light bulbs have an arc tube containing a metal vapor (mercury, in some cases) under pressure of several atmospheres. Instead of using ordinary line voltage to heat the arc tube, ac is converted to dc through a rectifier and then switched on and off to produce square waves at frequencies of 30 to 60 kHz. The square wave voltage heats the arc tube and the light stays lit. If the arc tubes cools below operating temperature while the lamp is in use, there is a restrike, and rf is generated again. Worst of all, as the lamp ages, restrike occurs more often. The square wave and higher harmonics raise havoc with nearby a-m radios, the interference level from a single bulb is of the same order as that of a light dimmer of the triac variety.

Because the rf bulb may come into widespread use, it is wise to see how the interference problem can be solved before the QRM factor becomes overwhelming.

The National Association of Broadcasters, concerned about the problem, conducted tests on the new bulbs, along with both inexpensive and expensive lamp dimmers. It was found that the more expensive dimmers had rf-suppression built in. Attenuated rf noise caused by their operation was about 8 dB for conducted measurements, and about 30 dB for radiated measurements.

The rf bulbs radiated about the same amount of noise as the inexpensive dimmers. The GE MaxiLight generated noise only during startup and restrike, which resulted in rapid bursts of noise. The Philips bulb, on the other hand, generated continuous noise.

The NAB and the FCC are discussing possible limitations on rf radiation from these devices. So far, nothing has been decided, and the best Amateurs can do is to make sure their receiving antennas are well removed from these rf pests. This is more easily said than done.

old coax never dies

How good is old coax? I had a 50-foot roll of coax in the garage unused since it was bought in 1944. Leaving it in its original coiled state, I shipped the coax back to Ron Stier, W9ICZ, at Belden Cable and asked him to check it, in his spare time, for attenuation. Was it contaminated? Had the rf loss increased over the decades? I pointed out that the cable had been protected from sunlight, but had been exposed to both high and low temperatures over the 42 years that had passed. He tested the cable, and this is what he found:

Frequency (MHz)	W6SAI cable	New, Standard cable
50	1.8 dB	1.6 dB
100	2.5 dB	2.2 dB
200	4.0 dB	3.2 dB
400	6.5 dB	4.7 dB
1000	12.4 dB	8.9 dB

Ron pointed out that up to 200 MHz, any difference in attenuation may be attributed to minor differences in cable manufacture, and cable made to the old JAN specifications did not have design requirements above 400 MHz.

It looks, then, that continuing ham-talk about contaminating and non-contaminating jackets and coax cable life are not necessarily valid, if care is taken in the use and storage of cable. Operating old cable under harsh environmental conditions may be another matter. But coax cable used in a protected environment seems to last forever — at least at frequencies below 200 MHz.

reference

1. "The Dearest Town in All New England," *Yankee*, November, 1986, page 166.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

the ubiquitous diode: part 1

If there's one solid-state component that's taken for granted and seemingly understood by all Amateurs, it's the diode. However, in discussions with fellow Amateurs, it's clear to me that although the basic concept of its operation is understood, its almost unlimited uses are rarely known.

For instance, when you mention diodes, most Amateurs think of power supplies, zeners, "idiot diodes" (if you don't use them, you're an idiot), detectors, and perhaps mixers. But there are many other types of diodes such as varactors, PIN, noise, Gunn, SRD, tunnel, LED, laser, photo, and so forth. These and other diode types are very important to VHF/UHF/microwave Amateurs.

This month's column will be devoted to the electrical and mechanical properties of the different types of VHF/UHF and microwave diodes. Next month's column will discuss specific applications using these diodes.

early solid-state diodes

The dictionary describes a diode as "a two-element electron tube or semiconductor through which current can pass in only one direction." This definition, however, doesn't mention anything about the diode's forward or reverse voltage/current characteristics, or its resistance, current handling capacity, junction capacitance, or applications.

Solid-state diodes were first described in a paper by Braun in 1874. However, they weren't used extensively until the days of the crystal radio sets to detect a-m from broadcast stations. This detection scheme — the process of changing rf to dc — is commonly referred to as rectification. Many years later, diodes were developed as low-voltage rectifiers for power supplies.

point contact diodes

Solid-state diodes are available in two major types, point contact and junction. Point contact diodes, the oldest solid-state type, date back to 1874 as noted above. They were the most common types used in the days of the crystal set.

The point contact diode is aptly named because in the early days it consisted of a piece of galena crystal (lead sulfide) or other suitable semiconductor material and a "cat's whisker" or fine wire that came to a point and contacted the crystal as shown in **fig. 1A**. By properly adjusting the point of contact on the galena crystal, a semiconductor junction is formed.

Low efficiency and the need to constantly readjust the contact on the early point contact diodes led to a change to vacuum tubes in the mid-1920s. However, by the early 1940s, solid-state diode performance was improved by the use of other semiconductor materials with better purity as well as different contact materials.

Some of the improved materials included but were not limited to copper oxide, carborundum, and selenium. Later yet, higher-performance materials such as germanium, silicon, and gallium arsenide became available. Development of materials continues to this day.

The improved point contact diodes performed well for many decades. Probably two of the most famous packaged point contact diodes were the 1N21 and 1N34 types, which are still in widespread use today. However, point contact diodes usually have limited current handling capacity and are difficult to reproduce in large quantities at low cost. They also are very fragile both mechanically and electri-

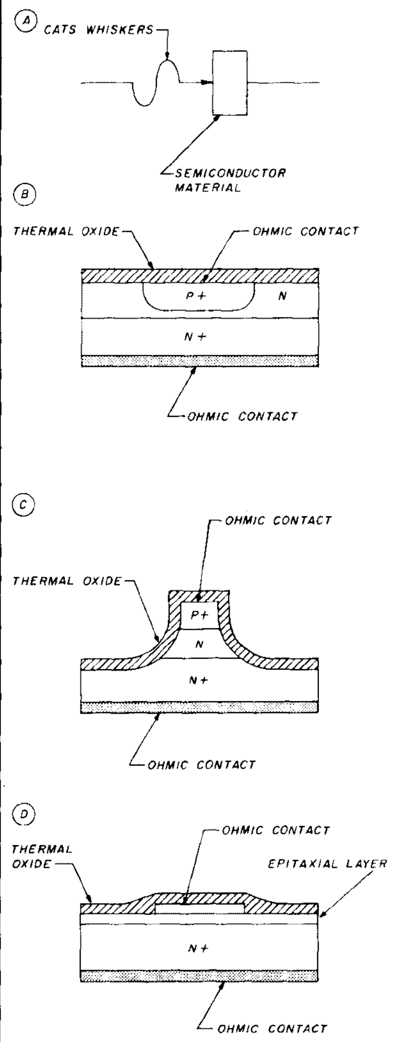


fig. 1. Typical diode construction: (A) point contact: (B) planar junction: (C) mesa junction: (D) hot carrier.

cally because the contact wire and junction are so small.

junction diodes

Fortunately an important technological breakthrough occurred when the Planar™ semiconductor manufacturing process was developed by Fairchild Semiconductor in the late 1950s. This patented process is now widely used to manufacture junction diodes, which offer both economy and repeatable electrical characteristics.

Most junction diodes are available in two geometries, *planar* and *mesa*. The typical planar geometry, shown in **fig. 1B**, resembles a flat plane. Note that the top of the diode is usually covered with a thermal oxide or overlay that adds some additional stray capacitance to the diode. This oxide is a result of passivation, a process meant to help seal the diode against external moisture and impurities.

The mesa geometry (**fig. 1C**), a variation of the planar type, was pioneered by Motorola, ostensibly to lower the capacitance across the junction of the diode. It supposedly takes its name from the geological mesa, a steep-sided hill with a flat top. I've also been told, however, that this geometry was named after the city where it was conceived — Mesa, Arizona — rather than from its apparent shape.

Usually less fragile than point contact types, junction diodes can be designed to have large current handling capacity. Many thousands of these diodes can be easily manufactured simultaneously on a single 2, 3 or 6-inch diameter semiconductor wafer and later divided into individual units.

Schottky diodes

By now you're probably wondering why I haven't mentioned the Schottky barrier or "hot carrier" diode. The reason is that it's a more recent configuration that works on an entirely different principle than the previously mentioned diodes.

The diodes discussed so far operate on the principle of minority carrier current, where the actual junction of the diode is buried within the semiconductor material. The hot carrier diode works on the principle of majority carrier current, where the rectification takes place right at the junction of the two materials.

The hot carrier diode was first theorized in 1938 by W. Schottky,[1] who described an idealized diode that would consist of metal contacts on a semiconductor material. The hot carrier diode as we know it today wasn't produced commercially until the mid-1960s. It uses the planar process but a different metalization scheme (**fig. 1D**).

electrical parameters of solid-state diodes

Let's first review some of the major characteristics of semiconductor diodes and the materials used to produce them. The most important electrical parameters of a semiconductor diode usually are forward voltage drop, reverse breakdown voltage, junction capacitance, and current handling capacity.

The forward voltage characteristic of a diode is a very important parameter. Often referred to as the "barrier" voltage or forward "knee," forward voltage is the minimum voltage required for a specific current to flow in the diode. In point contact diodes, this barrier voltage can approach zero volts. But in junction diodes, the barrier voltage is primarily a function of the solid-state material and the resistance of the metal contacts used to form the diode.

semiconductor materials

The most common semiconductor materials presently used in the manufacturing of junction diodes are germanium, silicon, and gallium arsenide. Germanium has the lowest barrier voltage, typically 0.3 volts at 1 milliampere of forward current at room temperature. However, germanium has poor thermal stability, especially as temperature increases.

Silicon is surely the most common semiconductor diode material in use today. When used in junction diodes it has a medium barrier voltage of about 0.6 volts at 1 milliampere. Silicon is plentiful, inexpensive to produce, easy to use, has good cutoff frequencies (typically greater than 10 GHz), and reasonable thermal stability.

The use of gallium arsenide in diodes is more recent. It is often used in the microwave and millimeter-wave spectrum since it has a much higher mobility and hence a higher cutoff frequency than either germanium or silicon. Its barrier voltage is high, typically around 1.1 volts.

The barrier voltage of a hot carrier diode is influenced by the semiconductor material as well as by the metalization contact materials. By changing the contact metals to the semiconductor material, the barrier voltage can be altered.

Hot carrier diodes usually use either silicon or gallium arsenide for the semiconductor material. Silicon hot carrier diodes have a typical barrier voltage of 0.3 volts, about half that of a typical silicon junction diode. Furthermore, hot carrier diodes can now be made with almost no barrier voltage. These devices are usually used as detectors and are often referred to as "zero-biased Schottkys".

For comparison, the typical low-level forward voltage versus current characteristics of point contact and junction diodes using germanium, silicon, and gallium arsenide are shown on the graph in **fig. 2**. Zero-biased as well as low, medium, and high barrier silicon hot carrier diodes are also shown.

Notice in **fig. 2** that as the current increases, the forward voltage drop across the diode increases. This is true because as current increases, there is an additional voltage drop across the total series resistance, R_T.

This total resistance is the sum of the series resistance, R_S, and the junction resistance, R_J, of a diode. This is shown schematically in **fig. 3** and in **eqn. 1** below.

$$R_T = R_S + R_J \tag{1}$$

where R_T, R_S, and R_J are in ohms. R_S is primarily a function of the resistance

of the connecting wire and the metalization resistance of the semiconductor material. R_J is a function of the forward current in the diode junction and can be approximated by:

$$R_J = \frac{26}{I_T} \quad \textbf{(2)}$$

where I_T is the total current in the diode in milliamperes.

For instance, if the series resistance, R_S, of a diode is 5 ohms and the forward current is 1.0 milliampere, the total resistance of the diode, R_T, will be approximately 31 ohms. At 10 milliamperes of forward current, the total resistance will drop to about 7.6 ohms.

R_T is very important since the higher the series resistance, the higher the voltage drop across the diode, and the lower the efficiency (especially at small signal levels). High series resistance also means that more power will be dissipated as heat in the diode.

It can be shown that to lower the forward resistance and raise the current handling capacity of a diode, the area of the semiconductor material must be increased. However, this usually increases the junction capacitance and hence decreases the maximum frequency of operation.

breakdown voltage

Reverse breakdown voltage is another very important electrical parameter of a semiconductor diode. Typically speaking, at low reverse voltage little (perhaps microamperes) or no reverse current flows through the diode.

Each diode has a specific reverse breakdown voltage at which the junction avalanches and high current flows, limited only by the resistance of the diode itself and any external resistance in series with the power source. If this avalanche current is not sufficiently limited, the diode will be destroyed quickly.

The reverse breakdown voltage of a diode is a function of the material and the metalization. **Figure 4** shows some typical breakdown voltages versus type of diodes. Generally speaking, it is only a few volts on the point contact and zero-biased hot carrier diodes used for low-level signal detection. On

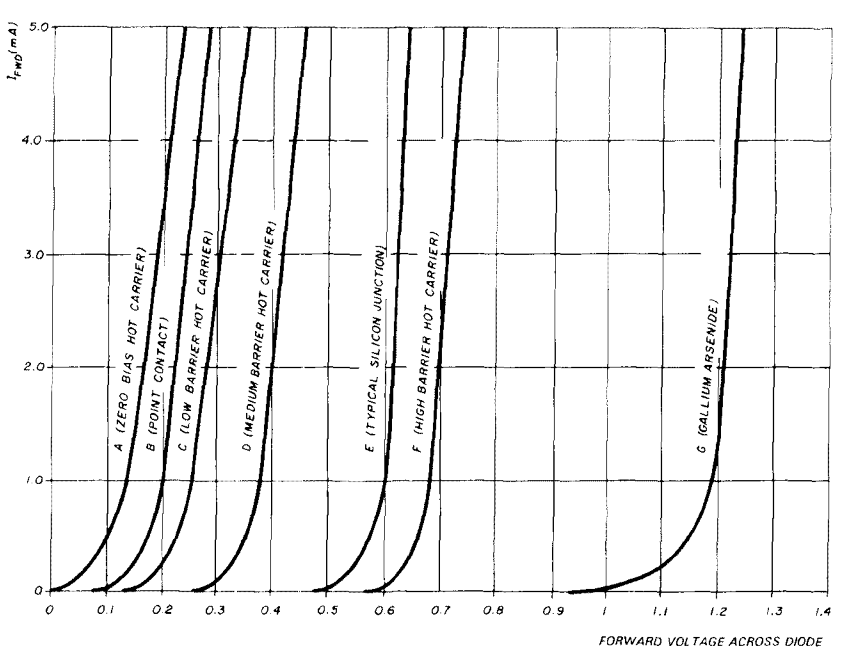


fig. 2. Forward voltage versus current characteristics of typical diodes: (A) zero-biased hot carrier: (B) point contact: (C) low-barrier hot carrier: (D) medium barrier hot carrier (the typical type): (E) silicon junction: (F) high barrier hot carrier: (G) gallium arsenide.

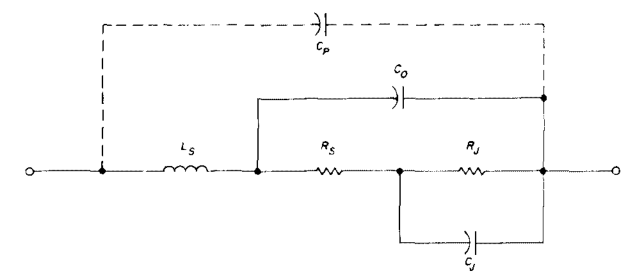


fig. 3. Equivalent circuit for a typical diode. C_j is junction capacitance, C_o is the overlay or passivation capacitance, C_p is package capacitance (if package is used), L_s is series inductance of package, R_j is junction resistance, and R_s is series metalization and bonding resistance.

the other hand, power supply rectifiers can have high reverse breakdown into the hundreds of volts.

diode capacitance

One of the most important parameters for high frequency operation is the total capacitance across the diode, C_T.

This capacitance is:

$$C_T = C_J + C_O + C_P$$

Referring to the equivalent circuit of a diode in **fig. 3**, C_J is the junction capacitance, C_O is the overlay capacitance (usually kept to a minimum, as described earlier), and C_P is the capacitance due to the package (if any), all in pF.

Package and overlay capacitance are fixed quantities, but junction capacitance decreases to some nominal value when the diode is reverse-biased. For detector and mixer diodes, this capacitance is usually measured at zero volts or at some low reverse voltage — for example, 1 to 4 volts (depending on the reverse breakdown

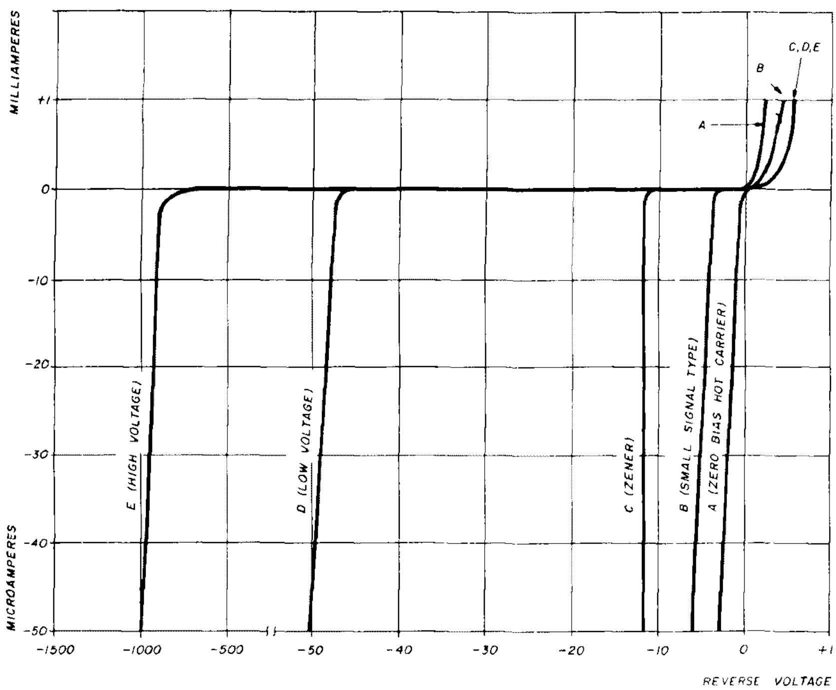


fig. 4. Reverse voltage breakdown characteristics of some typical diodes: (A) zero-biased hot carrier: (B) small signal type: (C) zener: (D) low voltage power supply type: (E) high voltage type.

voltage of the diode). The total capacitance of a typical UHF hot carrier diode versus bias voltage is shown in **fig. 5**.

The effect of the total capacitance on the operation of a diode can be envisioned intuitively. The greater the shunt capacitance, the more likely that the signal entering the diode will bypass the junction resistance, where it can offer the most rectification. Therefore the greater the total capacitance across the diode, the lower the maximum frequency of operation. The maximum frequency of operation versus junction capacitance for a typical hot carrier detector diode can be estimated based on the data shown in **table 1**.

Table 1. Typical maximum recommended junction capacitance versus maximum frequency of operation for hot carrier detector and mixer diodes.

Maximum Frequency in GHz	Maximum C_J in pF
0.1	0.7
0.3	0.6
1.0	0.45
3.0	0.35
10.0	0.22

tuning diodes

Capacitance in the junction of a diode is not always bad. If the semiconductor material is properly doped, a diode can be developed and used as a voltage-variable capacitor or tuning diode, which is often referred to as a "varactor" diode. Varactors are used in modulators, tuned filters, voltage-controlled oscillators, and frequency multipliers.

There are two major types of varactor diodes, abrupt and hyper-abrupt junction. In the abrupt junction type, the capacitance versus reverse voltage follows a logarithmic characteristic as shown in **fig. 5**.

Abrupt junction diodes are most often used where high *Q* and a moderate (i.e., 2:1 or 3:1) capacitance tuning ratio is acceptable. Most abrupt junction diodes are specified at a nominal capacitance with −4.0 volts applied across the junction, a defined tuning ratio, and *Q* at a specified frequency. The *Q* of a diode increases as frequency and the capacitance decreases. It is seldom desirable to operate a varactor diode with low reverse voltages (1.0 volts or less) since the diode may begin to rectify.

Hyper-abrupt junction diodes are most often used where very large (i.e., greater than 3:1) tuning ratios are required. Tuning ratios approaching 10:1 are possible. Hyper-abrupt varactors typically have lower reverse breakdown voltage specifications, are more sensitive to temperature variations, and usually have a lower *Q* than equivalent abrupt junction diodes. Furthermore, they are usually operated over a narrower tuning voltage range. For comparison, a typical hyper-abrupt tuning capacitance versus reverse voltage characteristic is shown in **fig. 5**.

diode packages

In extremely demanding applications, diodes are often used in chip form because this tends to lessen any parasitic elements in the operation of the diode. But this isn't always desirable, especially for Amateurs. Unpackaged diodes are small, fragile, and difficult to handle. Furthermore, they're often not hermetic, even when passivated.

As a result, most Amateurs prefer to use packaged diodes, which are not only easier to handle but also generally easy to remove or change if that becomes necessary. Therefore, it is very important that due consideration be given to the choice of the package.

One of the oldest semiconductor diode packages is the so-called 1N21 style, as mentioned above (**fig. 6A**). Polarity is usually marked on the package. In some versions, the diode package can actually be separated into two pieces and reversed if the opposite polarity is desired. This package is most often used for older and replacement point contact diodes.

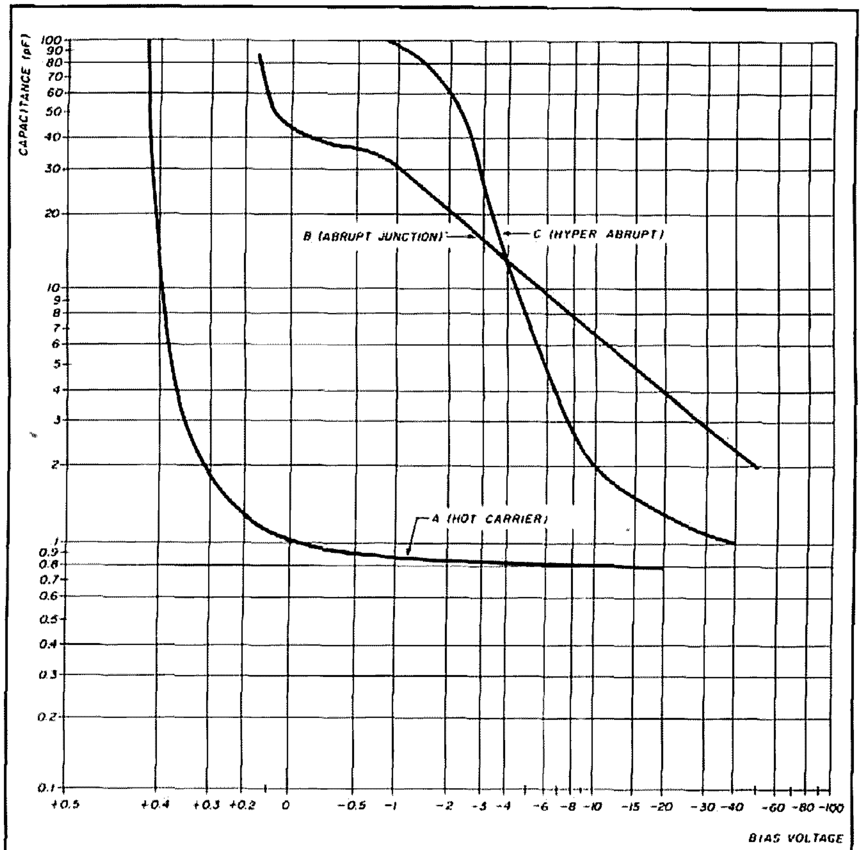


fig. 5. Diode capacitance versus bias voltage: (A) VHF hot carrier detector: (B) abrupt junction: (C) hyper-abrupt junction.

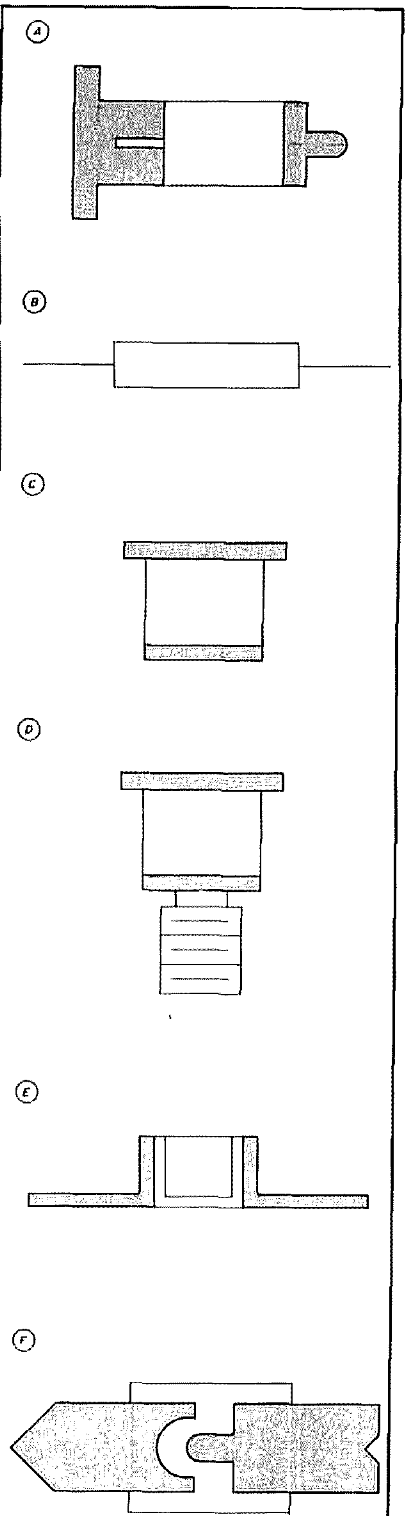


fig. 6. Some typical diode packages: (A) 1N21 type: (B) axial lead glass or plastic type: (C) microwave pill: (D) microwave pill threaded post: (E) stripline: (F) beamlead.

By far one of the most common diode packages used by Amateurs is the glass or plastic axial lead type (**fig. 6B**). The diode substrate is bonded to one lead of the package. The other package lead may be bonded by thermocompression to the other side of the diode lead if high reliability is required. Where economy is important, the second lead is usually attached to the diode with a whisker or pressure-type lead, which is often referred to as a "C" spring. This package usually has low shunt capacitance. However, it also has high (i.e., at least several nanohenries) series inductance shown as L_S in the diode equivalent circuit in **fig. 3**.

Another popular type of package is the microwave pill. Used where dissipation or extremely low inductance contact is required, it is shown in one form in **fig. 6C**. If heat is a real problem, the base of the package may be threaded as shown in **fig. 6D**.

Stripline pill type packages are also used (**fig. 6E**). In special situations, the beamlead diode is popular because it has the diode integrated into the leads as shown in **fig. 6F**. However, this type of diode mounting may also be difficult to handle because it's so small and fragile.

The choice of the proper package for a microwave diode is very important. Hundreds of different diode packages are now in common use. Each one has its advantages and disadvantages. When cost is important, some compromise in performance may be justified. However, in applications where the ultimate in performance is required, the package will be costly and perhaps difficult to use.

summary

In this month's column we discussed the basic electrical and

mechanical properties of VHF/UHF and microwave solid-state diodes. Other less well-known properties must be understood before you can choose the appropriate diodes for specific applications; some of these properties *will* be discussed next month. Other types of diodes suitable for specific applications will also be discussed. See you next month!

new dx records

In last month's column we updated all the latest North American DX records.[2] But as the January issue went to press, two more records were broken!

As predicted in that column, the 33-cm (903 MHz) record was further extended. On September 14, 1986, a Georgia VHF/UHF contest group signing WS4F/4, operating from Mount Toxaway, North Carolina (EM85MN), worked W4ODW in Niceville, Florida (EM60SM). This extends the 33-cm tropo DX record to 377 miles (606 kilometers). Congratulations to *all* involved.

I have also just been informed that the North American 9-cm (3456 MHz) tropo DX record was also broken by a comfortable margin when WB5LUA/5 in Mena, Arkansas, worked WA5TNY/5 in Fairy, Texas. I hope to include all the details on this contact in next month's column. Congratulations to Al and Rick!

Important VHF/UHF Events:

February 25:	*EME perigee*
March 21:	*±2 weeks. Optimum time for TE propagation*
March 24:	*EME perigee*

references

1. W. Schottky, "Naturwissenschaften," *Z. Physics*, Volume 26, 1938, page 843.
2. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-Wave Update," *ham radio*, January, 1987, page 63.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

testing components

A basic question often asked is how to test diodes. You can use an ohmmeter to measure the diode's resistance in both directions. If the diode conducts current in only one direction, you'll find — as expected — a large, seemingly infinite resistance when the ohmmeter probes reverse-bias the diode under test. When the probes forward-bias it, you'll find a very low resistance.

For small signal diodes, use the X100 or X1000 scales of a VOM; for power supply rectifiers, use the X1 scale. Note the values obtained in both directions. The positive (the red lead, normally) should show low resistance; the second reading (with leads reversed) should be very much higher than the first.

What does "very much higher" mean? When I first started out as an apprentice technician in 1959, selenium rectifiers showed only a 2:1 ratio between forward and reverse resistances; 500-mA silicon rectifiers (which were all in "top-hat" packages in those days) showed 5:1 or so. Later, the 1N4xxx-series devices showed 10:1 or greater. Similarly, germanium small signal diodes (1N34, 1N60, etc.) showed 5:1 when good, while silicon devices (1N23, 1N914, 1N4148, etc.) showed 10:1. Modern varieties of these same diodes show 100:1, according to ohmmeter tests that I ran for this article. Keep the older values in mind, however, because "antique" diodes tend to show up in bargain packs, in older equipment under repair, and in hamfest "specials".

testing SCRs

Although silicon controlled rectifiers (SCRs) can be tested with an ohmmeter in a similar manner, it's first necessary to determine whether or not the gate of the SCR is capable of controlling the diode. Three questions must be asked. Will the gate turn on the device? Does the SCR act like a regular diode after turn-on? And does it turn off when the current drops below a certain value?

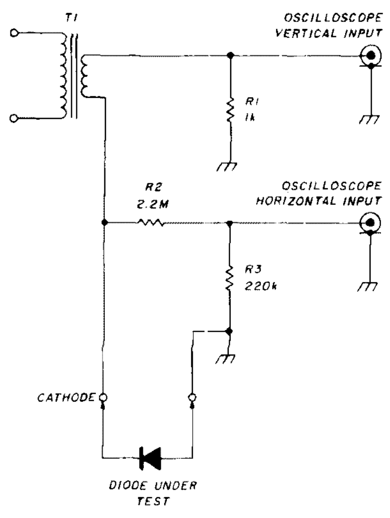


fig. 1. Simple diode curve tracer can be constructed using available oscilloscope and a few additional components.

The gate circuit can be tested by connecting the positive ohmmeter probe to the SCR's anode and then taking a resistor (experiment with the value, which depends upon turn-on current of the SCR) and connecting it between the anode and gate. The resistance of the SCR should be high before the resistor is connected, and low afterwards. After turn-on, remove the resistor. The SCR should still conduct. Disconnect the positive probe and then reconnect it. If the SCR is good, the resistance will again be high. Note: this method works only on low-current SCRs; the ohmmeter current is less than the hold-on current of high-amperage SCR devices.

Because other (parallel) circuit resistances can affect results, testing diodes with an ohmmeter is done out of circuit. When troubleshooting, disconnect one end of the diode before attempting to test. In dc power supplies, there are good reasons to disconnect both ends of the diode under test. Stored charges, even in low-voltage circuits, can destroy the diode — or even the ohmmeter — in the event of a mistake. Considering the voltages present in high-voltage power supplies, it can also be dangerous.

VOM versus DMM

VOMs typically used a 1.5-volt battery in the ohmmeter circuit. Bench model vacuum tube voltmeters (VTVM) also used 1.5-volt batteries (or electronic power supplies in a very few models) for the ohmmeter, even though they were also powered from the 110-volt ac line. Be careful when using ancient VOM/VTVM instruments, by the way; some pre-1955 models used 22.5-volt batteries for the ohmmeter, and these instruments will blow every diode you try to test. Suspect this as the cause if you're using an older instrument, or if every diode you test seems to be shorted (they are!).

Modern digital multimeters typically use low-voltage sources for the ohmmeter function. The voltage levels used won't forward-bias the diode, so the diode will test open. Most instruments of recent design have a "high-power" ohmmeter function specifically for testing diodes. The high-power function will sometimes be marked, but in most instruments it's

designated on the function switch with just a diode symbol. On a few instruments, a Hi/Lo Ohms switch is used for exactly the same purpose.

One reader wrote to ask why different meters give different readings in diode testing. This is because different meters use different voltage sources and have different internal circuit resistances. This same effect is seen when switching scales on the same ohmmeter.

matching diodes

Matched diodes are needed in a variety of circuits — for example, in ratio detectors, in discriminators and other fm demodulators, and in quadrature phase detectors, which are used in instrumentation applications. With modern diodes and most circuits (note the caveats!), diode matching isn't necessary unless you're trying to squeeze every last little drop of performance out of the circuit. Some replacement part manufacturers offer matched pairs of 1N60 diodes for high fidelity fm tuners; in communications applications, diode matching is only rarely important.

If you feel you must match diodes, use an ohmmeter to measure the forward and reverse resistances of several diodes, selecting those with the closest resistance readings.

build a simple diode curve tracer

Figure 1 shows a method by which an oscilloscope can be used to trace the I vs. V curve of a PN junction diode. Transformer T1 is a low-voltage filament transformer. I used a 25.6-VAC, 300-mA model, but anything from 6.3 VAC to 26 VAC can be used. The high resistances, effectively in series with the diode under test, prevent burn-out. **Figure 2** shows several oscilloscope traces under various conditions. **Figure 2A** shows the normal diode trace for a good 1N914; **fig. 2B** shows the trace for an open diode. **Figure 2C** shows a shorted diode, and **fig. 2D**, a very leaky diode (simulated by shunting 2.2 k across the 1N914).

additional notes on transistor substitution

In recent columns (September and October, 1986) we discussed transistor substitution. A reader from California reminded me of something I'd seen in repair shops a decade ago but forgotten. When dealing with older equipment, or with project circuits designed more than 20 years ago, be careful in making substitutions with modern devices. In fact, you can even run into problems with transistors of the same type number, but of modern manufacture. The problem is two-fold.

First, older transistors didn't attain the frequency specs that modern transistors do. Even though recently manufactured units may have the same type number, they'll now have a much higher frequency response. This situation is especially likely when using a substitute from a replacement line, where the original type is no longer available but a "better" substitute is offered. Years ago, circuit designers didn't have to worry as much about layout and stabilization because the transistor was self-limiting. At frequencies where oscillation could occur with a high-frequency device, the gain was too low to support Barkhausen's criteria for oscillation; that isn't the case today. If a high-frequency transistor is substituted for an older device, it might oscillate.

Second, the C-E, C-B and B-E leakage resistances were much worse in older devices, and designers had to compensate for these parallel resistances in the circuits. As a result, a circuit that is properly biased using older devices is not properly biased for the modern replacement. In the late 1960s I worked in a car radio shop after engineering school every day. I once

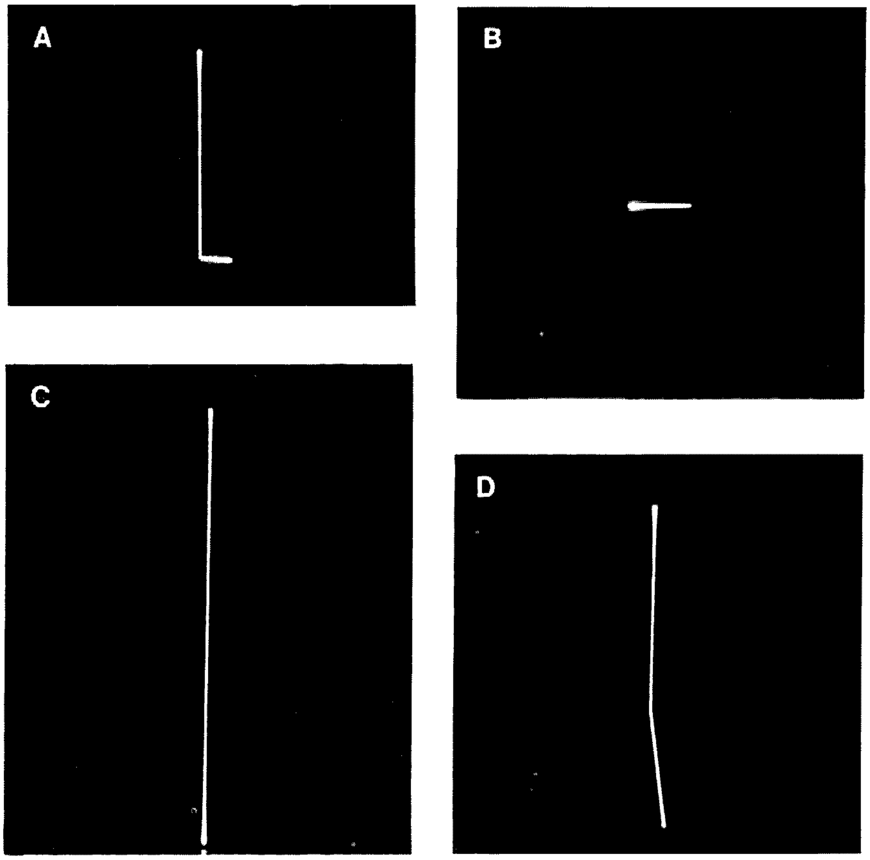


fig. 2. Oscilloscope used as diode curve tracer: (A) good diode (1N914); (B) open diode; (C) shorted diode; (D) leaky diode.

asked a tech rep from one of the major auto radio makers why his company had switched resistor values when the new radio used the same device number in the same circuit. He explained that new production transistors (they were Ge, not Si) were much better in terms of leakage resistance.

Be careful.

NOTE: If you have any tips, techniques, or questions you'd like to see discussed in this column, please contact K4IPV at P.O. Box 1099, Falls Church, Virginia 22041.

ham radio

short circuit

vhf/uhf world

The following text should accompany **fig. 3** of W1JR's December, 1986, column: *The boom is 1-inch square tubing with 0.062-inch wall. One-inch diameter round tubing may be directly substituted, as discussed in the text, though with decreased mechanical strength. The boom should be supported as discussed. All elements are made from 3/16-inch diameter aluminum rod and pass through the boom with insulated shoulder washers and keepers as described. The ends of all elements should be bevelled approximately 1/32 inch. The length of the driven element and/or the spacings and lengths of the T-match are not critical and may have to be modified slightly to obtain a low (1.2:1 maximum) VSWR.*

Figure 3 should include the following note in the second part of the figure: *Note 3: The UG21 connector is attached to the boom with an L-shaped aluminum plate approximately 1.5 by 1/16-inch thick. Drill out two of the UG21 connector holes with a 0.142-inch diameter drill. Prepare a 4:1 (200-50 ohm) $\lambda/2$ type balun made from an 11.0-inch piece of 0.141-inch diameter, 50-ohm semirigid coax with 3/8 inch of the outer tubing stripped off each end and 1/4 inch of PTFE removed for connection to the T-match. Bend the coax in a "U" shape and pass the two ends through the two drilled-out holes in the UG21 connector. Solder the coax on both sides where it passes through the connector.*

mmic multiplier chains for the 902-MHz band

Doublers with gain and simple filters produce reliable results

It's possible to design a simple frequency multiplier chain for UHF and microwave transceiving converters using stable and easily reproduced silicon MMIC (Microwave Monolithic Integrated Circuit) amplifier blocks. In this article, I'll first discuss the use of MMIC amplifiers as multipliers, then describe a specific application — a local oscillator for the 902-MHz band.

MMIC multipliers have gain

The key to the design of this multiplier chain was the realization that silicon MMIC amplifiers not only make good active multiplier stages, but can also provide gain — i.e., the harmonic output power level can be greater than the fundamental input power. MMIC amplifiers offer several advantages over more conventional active multipliers. First, MMIC amplifier "building blocks" are internally matched and unconditionally stable, so there's no need to worry about pulling them into spurious oscillation modes, as can happen when a discrete transistor multiplier is tuned with external networks. MMIC amplifiers are small and inexpensive, too, and consequently attractive for multiple use. Unfortunately, they require a fair amount of dc power to operate.

initial tests

The Avantek MSA 03 MMIC was tested for use as a multiplier. It was biased normally and an input signal at 0 dBm was applied. The second harmonic, viewed on a spectrum analyzer, was typically 10 to 15 dB below the fundamental *output*. Since the gain of the MSA 03 is about 12 to 14 dB, the second harmonic is about equal in power to the drive signal. This suggests that to build an active doubler with this MMIC, all that's required is a filter to reject the fundamental output and enhance the desired second harmonic.

higher order multiplication has disadvantages

Of course it's possible to multiply by a number other than two. Triplers and even quadruplers aren't uncommon in transistor multiplier circuits. However, there are a couple of factors that led me to use only doublers. First, the gain of a multiplier falls off as the multiplication factor is increased. As discussed before, to get unity or greater gain with an MMIC multiplier, a doubler is most effective. Second, the filtering is simplified when doubling, since the *undesired* products are 50 percent away from the desired passband. This ratio decreases for higher order multiplication, to 33 percent in a $\times 3$ multiplier and down to 25 percent for a quadrupler.* As the fractional bandwidth between desired and undesired products narrows, the filter complexity increases to maintain a given amount of rejection. In the interest of keeping the filtering simple and easy to tune, I elected to go to the higher number of stages needed for doublers and pay the price in increased power consumption. This approach worked, since the multiplier chain proved easy to tune and results were repeatable. No undesired spurious oscillations were encountered at any time during the development of these MMIC multiplier stages.

filters *are* needed

Filters are the key elements in the multiplier chain. Each MMIC stage must be followed by a filter to remove the fundamental while at the same time passing the desired second harmonic. Much of the justification for using doublers was to permit the use of simple, easily tuned filters.

At lower frequencies it's easy to build filters using lumped circuit techniques and designs provided in the

*For example, when doubling 100 MHz to 200, the nearest undesired products are the fundamental (X1) at 100 MHz and the third harmonic at 300 MHz. Each is separated by 50 percent from the desired 200-MHz output. Similarly, when tripling 100 to 300, the undesired X2 and X4 products are 100 MHz away, or 33 percent of the 300-MHz center frequency.

By Jerry Hinshaw, N6JH, 142 Kensington Place, Frederick, Maryland 21701

literature.[2,3] As one approaches UHF, it becomes more difficult to control the stray capacitances and inductances, and individual components themselves resonate in undesired ways. At this point, it's good to change over to another type of filter, one that's more appropriate to UHF work. It would be nice if such filters were also simple, easy to tune, and fit in well with the other circuitry.

The two higher-frequency bandpass filters were designed using printed inductors (printed coupled microstrip transmission lines). This was done for several reasons. First, at higher UHF frequencies, pure inductances in lumped element filters are smaller and more difficult to make, while the printed coupled lines are easier to construct. In addition, once the coupled lines are designed and printed on the circuit board, they have known, stable characteristics.

These filters are the equivalent of the familiar combline bandpass filters often encountered in microwave work. The difference is that here the usual air-dielectric resonator rods have been replaced by a microstripline version. The two lines, shorted to ground at one end, and capacitively loaded at the far end, are coupled by the electric fields both in the dielectric substrate and in the air above the microstriplines. Here, the substrate is the usual Amateur microwave printed circuit board material, G-10. The coupling between the lines depends mainly upon their width, the spacing between them, and their lengths.*

A number of references contain graphical aids to the design of coupled line pairs, and earlier articles describing the use of similar structures have appeared in the Amateur literature.[4] Several CAD programs including models for coupled lines on microstrip are available; I used such a program to optimize the design of the two filters incorporated in this multiplier. The mechanical details of the filters are given in the PC layout (**fig. 3**).

The characteristics of these filters include good low-frequency response, with no undesired passband below the center frequency. They also offer good high-frequency response up to approximately three times the center frequency. Near the third harmonic, the rods are again quasi-resonant, and there is a second, undesired passband. However, in a multiplier, this band is at approximately the sixth harmonic of the doubler's input signal, and it has generally not caused any problems because the sixth harmonic is quite low in power.

These coupled microstripline filters are also easy to tune to their center frequency because their response is fairly broad. The microstriplines, once printed on the substrate, are, of course, unadjustable, so that only the two trimmer capacitors have to be tuned. Fixing the inductors by printing them on the board has its advantages: fixed-tuned inductors need not be blindly tuned, and it's easier to avoid tuning to the wrong harmonic when the tuning range is restricted.

The other main ingredient in this type of multiplier is the active stages. Here, they are MMIC amplifiers, silicon integrated circuits designed to provide very wideband gain. Packaged in small, transistor-like plastic housings, they contain almost all of the biasing and matching circuitry for a complete rf amplifier. Devices from Avantek have been described in a number of publications recently.[5,6,7] In addition, a new, even lower-cost entry into the MMIC field has been announced by Mini-Circuits Labs.[8] Other manufacturers will undoubtedly announce silicon MMICs of their own soon. Most of these amplifiers are suited for multiplier use if they're driven to near saturation. All are unconditionally stable, which is a great aid to the design of a multiplier gain stage with a reactive filter terminating the output. The multiplier described below uses Avantek amplifier MMICs, but other similar devices could probably work as well.

a local oscillator circuit

A multiplier based on MMIC gain blocks represented an easy and repeatable design approach to 902-MHz band operation. I wanted to build a converter that would translate this band down to the 144-MHz band so that I could use my 2-meter transceiver; doing this would call for a local oscillator operating at approximately 758 MHz. A local oscillator (LO) 144 MHz above the operating frequency would also be possible, but that would invert the sidebands in an SSB system, and otherwise offer no particular advantages.

The choice of exact LO frequency is worth a moment of thought, as many UHF operators have discovered (the hard way) in the past. It's best not to choose an LO frequency that will produce undesired responses at the i-f. Here, we must avoid a local oscillator frequency whose harmonics fall in-band either on the 2-meter i-f or within the 902-MHz band. A second possible problem can occur when there's a strong signal at the i-f from external sources — for example, if the i-f is 144.2 MHz when operating on the suggested calling frequency of 903.1, there will be problems with i-f feedthrough of strong signals on 144.2. These signals leak around the converter and appear on top of the real signals downconverted from the 902-MHz band. It can be difficult to shield the i-f sufficiently to avoid this entirely, so it's prudent to pick a less congested frequency for the i-f. In my area, 144.5 is usually quiet. So, for my example, the LO was designed at $903.1 - 144.5 = 758.6$ MHz.

Because I wanted to use only doublers in the multiplier chain, the choice of multiplication factors was restricted to powers of 2, with 4, 8, or 16 the most

*for a given substrate material and thickness.

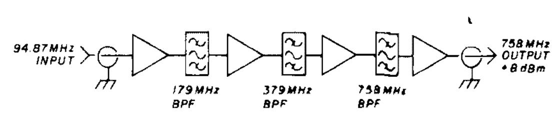


fig. 1. Block diagram of the X8 multiplier.

758.6 MHz, is further amplified after filtering to produce a power level sufficient to drive a standard-level double-balanced mixer.

The first bandpass filter, centered at 189 MHz, consists of two series-resonant sections and a single capacitive shunt element. The series sections use air-wound coils. I've long found inductors of this type

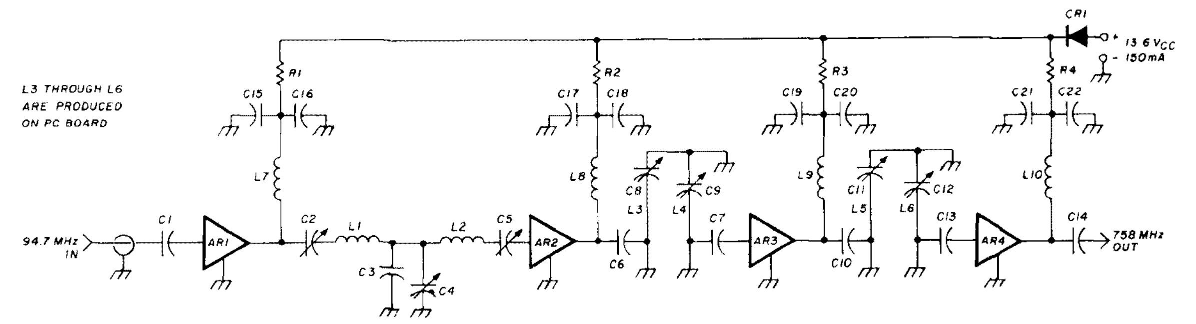


fig. 2. Schematic diagram of the multiplier.

reasonable choices. However, if the total multiplication were only 4, the crystal operating frequency would have to be approximately 188 MHz. Such crystals are available, but they're neither common nor economical. Three doublers in series gives a multiplication of 8 and calls for an input of about 94 MHz, which is a readily available frequency in common series-resonant, fifth overtone crystals. Four doublers would yield a X16 output, with a crystal at 47 MHz, but there appears to be no reason to go beyond an X8 stage. I ordered a crystal for

$$\frac{758.6}{8} = 94.825000\ MHz$$

The block diagram of this LO chain is shown in **fig. 1**. The crystal oscillator's (approximate) 94-MHz output is buffered and amplified by an MMIC stage, which drives a lumped element bandpass filter centered on 189 MHz. (See schematic of MMIC multiplier chain in **fig. 2**.) This filter presents a good VSWR at its center frequency, but a very poor match at the oscillator's fundamental operating frequency. The fundamental output of the amplifier is reflected back into the MMIC, where it has a second chance to contribute to second harmonic output.*

Though the next two multiplier stages are similar in design, they differ mainly in that their bandpass filters use coupled microstriplines rather than lumped elements. At each stage, there's an MMIC amplifier driving a bandpass filter tuned to the second harmonic of the MMIC's input frequency. The final output, at

*I have no idea if such conversion is significant; however, it would be interesting to experiment.

Parts list for the multiplier.

AR1-4	*Avantek MSA0304 MMIC Amplifier*	
C1,6,7,15, 17,19,21	*0.01μF ceramic disc capacitors*	
C2	*1.7 pF*	*nominal 0.8-8pF*
C5	*1.7 pF*	*trimmer capacitor*
C11	*3.9 pF*	*nominal 0.8-8pF*
C12	*3.9 pF*	*trimmer capacitor*
C3	*10 pF ceramic capacitor*	
C4	*2-8 pF trimmer capacitor*	
C8	*10 pF*	*nominal 4-20 pF*
C9	*10 pF*	*trimmer capacitor*
C10,13,14	*33 pF chip capacitor*	
C16,18,20,22	*0.01 μF (non-critical value)*	
CR1	*Silicon rectifier diode 1N4002 or equivalent*	
L1,L2	*16-1/2 turns No. 24 AWG, 0.3μH. Bare wire wound in threads of nylon 6-32 screw.*	
L7,8,9,10	*10 to 15 turns No. 30 AWG Kynar insulated wire-wrap; Wire close-wound on No. 60 drill.*	
R1-4	*200 ohm, 1/4-watt carbon composition*	

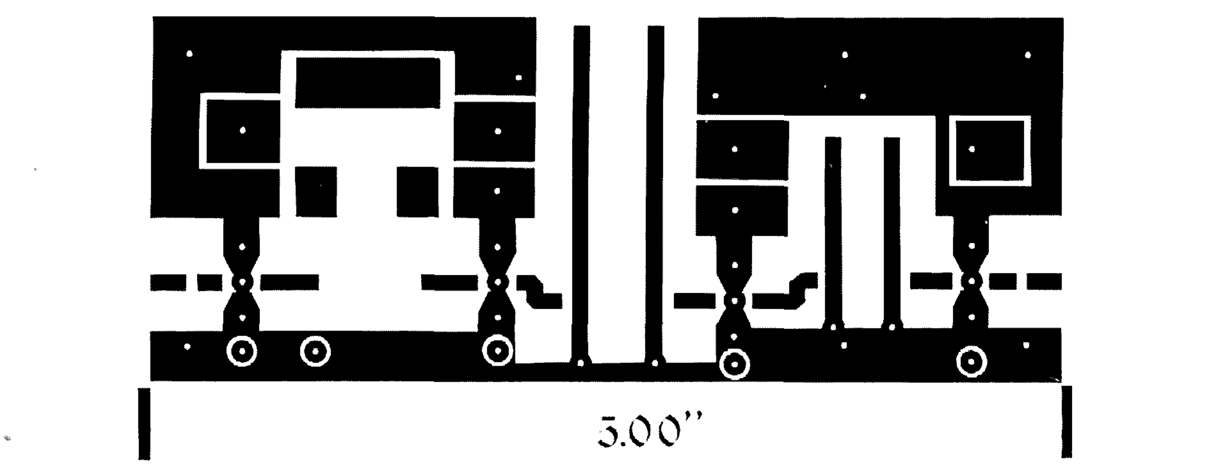


fig. 3. Full size PC negative for the X8 multipler. The other side of the 0.062" G-10 board is unbroken copper groundplane.

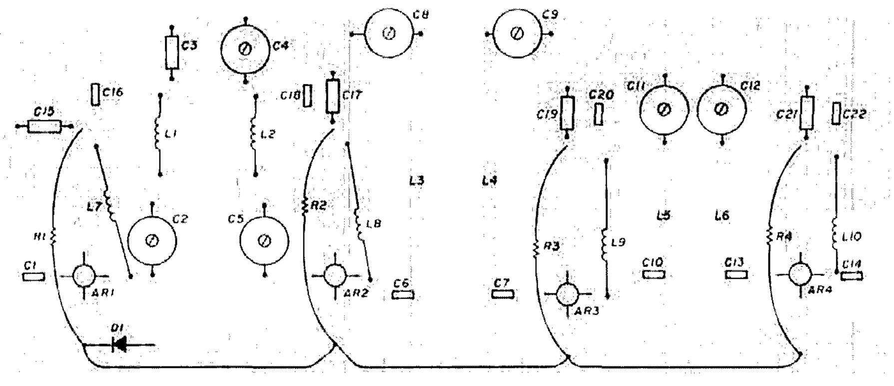


fig. 4. Component locations for the multiplier. Components shown with dashed lines are on the back side of the board. Eyelet locations are shown as an X.

hard to predict, mainly because of the difficulty in winding the coil to the design's dimensions. For this reason, I wound the coils on a form — a nylon screw. The No. 24 wire lies in the threads neatly and evenly, so that the predicted coil spacing is maintained. The nylon apparently doesn't cause an excessive increase in the filter insertion loss, even though nylon is generally a poor rf material. (This simple coil form is available at better hardware stores.) Variable capacitors are used to provide tuning range for the filter. The two capacitors in the series arms of the filter are the main tuning, while the adjustment of the shunt element is not as critical.

The second and third filters, centered at 379 and 758 MHz, were made with printed microstriplines. The key to their performance is in the accurate reproduction in copper of the design dimensions. It isn't necessary, however, to maintain fantastic accuracy; a number of filters have been built with hand-cut lines and work well. Pay attention to the grounding (as always in rf work, poor grounding will rise to cripple otherwise fine circuits). An eyelet at the base of the filter is good insurance, as is wrapping the edge of the top ground traces to the bottom ground with foil and soldering both sides.

The loading capacitors at the ends should be physically small, electrically short, and high Q. That's the ideal. In practice, adequate filtering is achievable with a wide range of capacitors. The best capacitors for the job seem to be the subminiature microwave tubular trimmers, but the circular ceramic types work, too. The main problem with lower-cost ceramic capacitors is really only an irritation; their entire tuning range is compressed into one-half turn of the rotor, so that fine peaking of the filter requires a steady hand and patience.

The only other main concern in the layout is a familiar one in all high-frequency work — the substrate.

The microstriplines require a good ground plane on the far side of the board, a ground plane that should be as unbroken as possible, and well coupled to the ground traces on the top of the board. The thickness of the material is important, too, if the line impedances are to be as designed. Ideally, the dielectric constant of the material should be well controlled, but in practice most Amateur construction is done on G-10 board, which is not intended for microwave work. However, G-10 works well enough for noncritical circuitry. The dielectric constant of G-10 varies with frequency, but is about 4.2 at the high end of the UHF band.[9]

Each MMIC is mounted to the surface of the board with its plastic package recessed in a clearance hole. The amplifiers receive their dc bias via a small decoupling coil, well bypassed to ground at its far end. The MMIC operating voltage is obtained from the 13.6-volt supply and dropping resistor. The resistor is positioned on the bottom side of the circuit board to keep it out of the way. More details of device biasing are given in the references.

construction

The printed circuit board negative shown in **fig. 3** depicts only one side of the board. The other side of the circuit board is unetched copper, which serves as a ground plane for the microstriplines. Component placement is indicated in **fig. 4**. Where component leads pass through the board, small clearance holes should be made to prevent the leads from shorting to ground. Ground plane side artwork isn't needed, since no circuit traces exist on this side, and a few minutes' work with a drill bit will clear the lead holes.

The board doesn't have to be all that precise; the filters are tolerant of inaccurate layout because of their low selectivity. In fact, I've had good results with handcut boards. I make a 1:1 photocopy of the artwork and glue it to the surface of a piece of G-10 board. Then I use a sharp knife and cut through the paper to nick the copper cladding. I then peel the cladding away with the knife and a pair of pliers. The results aren't particularly attractive, but the process is quick and effective.

The crystal oscillator circuit is similar to the one described in Hilliard's article,[10] which was designed to operate around a 2N4124 at 16 percent lower frequency. It's also quite similar to designs described in detail in Frerking.[11] The oscillator uses a fifth overtone crystal, with resonant network in the feedback path to peak the circuit's gain at the desired overtone. Only one minor alteration was needed to get the circuit working: the base of the oscillator transistor requires a good rf ground, and when using only a disc capacitor as a bypass, I had problems with spurious modes and poor starting. I added a small (physically and electrically) chip capacitor to ground and the problems vanished. The final circuit is shown in **fig. 5**.

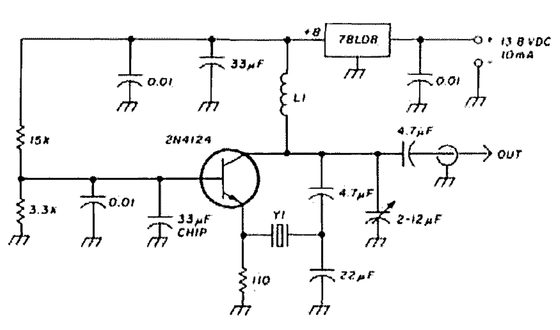


fig. 5. Schematic diagram of the 94 MHz crystal oscillator.

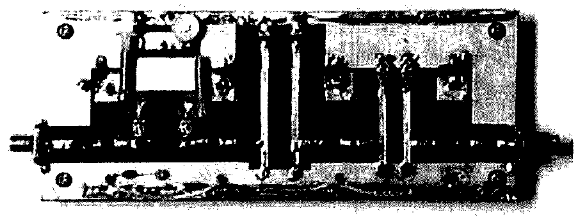


fig. 6. Photograph of the prototype multipler, which was built on hand-cut board.

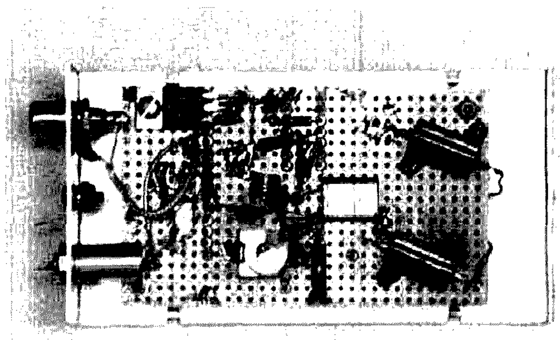


fig. 7. Photograph of the prototype oscillator in its shielded housing.

The oscillator (**fig. 7**) was built on a piece of copper-clad board. I didn't make a circuit board for this circuit because I felt the layout wasn't particularly critical. Where insulated mounting points are needed, a teflon-insulated terminal can be installed on the board, or an isolated island of copper can be cut with a pad cutter. Many of the construction details are visible in **fig. 7**.

This design, like most oscillators, tends to be sensitive to variations in its environment. Stray fields, temperature variations, load variations, power supply changes and even nearby movement can alter the operating frequency. The oscillator's output is multiplied eight times before mixing, so even changes of a few hertz can be noticed at the output of a narrowband converter (consider how a 50- to 100-Hz step can change the pitch of an SSB voice signal). For these reasons, I chose to put the oscillator in its own shielded box, use a voltage regulator, and leave room for a temperature controller.

Shielding helps prevent changes in the local fields of the circuitry and helps lengthen the oscillator's thermal time constant. It's important to note the distinction between temperature compensation, which reduces the total drift of the oscillator, and changing the thermal time constant, which reduces the rate of change of frequency, but not the ultimate magnitude of the change. In an Amateur system, it's usually unimportant if the circuit drifts a bit, as long as the drift rate is quite slow. After all, we don't tend to sit on one frequency for hours (or even for many minutes). So lengthening the thermal time constant is a good strategy for UHF oscillator circuitry, and is easier than temperature compensation or control.

The closed aluminum box, stuffed with fiberglass insulation, helps greatly in slowing the drift rate. The two large resistors visible on the board in the photograph were included for use as heaters if a temperature controller were needed. So far, I haven't seen any need, but if the local oscillator were mounted outside and exposed to wide temperature ranges, temperature control could be added. The space between the two power resistors is sufficient for an LM3911 integrated circuit temperature regulator.

tuning

Start the tuning process by getting the oscillator going. If all is well, the oscillator will start up as the variable capacitor is adjusted. The adjustment range of the capacitor should be broad. Set the capacitor to the middle of the range, making sure that the oscillator will restart when power is interrupted. The oscillator should provide 5 to 10 milliwatts at the output of the attenuator. There is no trimming of the series resonant crystal.

Unfortunately, tuning the multiplier can be more complicated. The tuning range of the three filters is limited, so it should be difficult, *but still possible*, to tune to the wrong harmonic. Start by presetting the variable capacitors to the calculated capacitance. For example, the output filter calculations predict that 3.9 pF wil be needed, so if a 2- to 8-pF trimmer is used, preset it visually to about half-meshed. The calculated values for all of these capacitances are shown on the

schematic diagram.

Apply the oscillator output signal to the multiplier, and then apply dc power. See that the MMIC device voltages specified are present, which should verify that the amplifier stages are working. Peak the output for maximum power and measure the output frequency with a counter.

I found that this tuning could be accomplished with just a diode detector to peak the tuning and a counter to verify that the output of the multiplier was at the correct frequency. I then examined the ouput of the chain with a spectrum analyzer, which produced the plot shown in **fig. 8**.

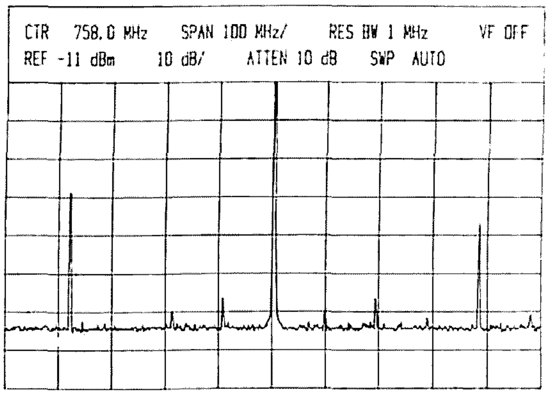


fig. 8. Spectal output plot of the multiplier chain. The desired signal is at +9 dBm. The highest undesired products are at 379 and 1137 MHz, approximately 30 dB down the 758 MHz signal.

If this method of tuning doesn't work, it might be better to tune each stage separately. Tap into the circuit at the output of each filter in turn, and peak it for best output power at its center frequency. This method will take longer, but it's less "blind" than tuning for the final 758-MHz output all at once.

summary

MMIC devices in circuits similar to the one just described can be configured as simple and well-behaved multiplier chains. Silicon MMIC amplifiers now provide good gain to 3 or 4 GHz, so that multipliers using them should be practical to at least such frequencies. The concept outlined here — using doublers followed by simple filtering — provides adequate spectral purity and output power sufficient to drive a mixer directly. The components are inexpensive, and no machine shop work is needed. The only real drawback to this cascaded system is its healthy appetite for dc power due to the MMIC's internal biasing circuitry. The phase noise of the multiplier wasn't measured, but it appears to be quite adequate for Amateur narrowband communications.

parts

I can provide some of the parts for this project, including printed circuit boards; send an SASE to me for a list of what I have available.

references

1. E. H. Angle, "A Quarter-Kilowatt 23-cm Amplifier, *QST*, March, 1985, page 14.
2. D.R.J. White, *A Handbook on Electrical Filter Synthesis, Design, and Application*, Don White, Germantown, Maryland, 1963.
3. William Orr, W6SAI, *Radio Handbook*, 22nd Edition, Howard Sams, Indianapolis, Indiana, 1981, page 3.33.
4. L. Young, *Microwave Filters Using Parallel Coupled Lines*, Artech House, Dedham, Massachusetts, 1972.
5. J. Hinshaw, N6JH, "Monolithic rf Amplifiers," *ham radio*, March, 1986, pages 22-33.
6. Bob Atkins, "Microwave Amplifiers," *QST*, January, 1986, page 78.
7. Craig Snapp, Jose F. Kukielka, and Northe K. Osbrink, "Practical Silicon MMICs Challenge Hybrids," *Microwaves and RF*, November, 1982.
8. "A 99-Cent Monolithic DC to 1000-MHz Amplifier," Mini Circuits, *Microwave Journal*, August, 1986, page 131.
9. Alan Wood, "A 30-Watt, 800-MHz Amplifier Design," Engineering Bulletin EB105, Motorola Corporation, Phoenix, Arizona.
10. D. L. Hilliard, "A CW Transmitter for 902 MHz," *QST*, March, 1986, page 32.
11. Marvin E. Frerking, *Crystal Oscillator Design and Temperature Compensation*, Van Nostrand Reinhold, New York, 1978.

ham radio

the weekender

the weekender: a mobile theft deterrent

Are you concerned that your car — and your prized mobile equipment — might be stolen? If you are, read on. . . because this circuit will let your car *fight back* if it's stolen.

It's almost impossible to stop a really determined thief from trying to steal your car. Alarms may discourage amateurs, but seldom deter professional thieves, who know that most people passing by a sounding alarm will just keep on going.

The circuit described in **fig. 1** allows a car to be driven for about 60 seconds. During that period, the car may be driven to a busy intersection or roadway, where it will stall, never to be started again by the thief. It would be possible to prevent the engine from starting in the first place; however, this could irritate the thief and invite vandalism. It's safer, and usually less costly, to allow the car to be driven briefly, creating a situation in which the thief will be placed in a vulnerable position and possibly caught. At the very least, your car will be abruptly abandoned, minimizing the possibility of vandalism. You may have to pay for towing — and possibly a charge for impoundment — but you'll have your car.

do's and don'ts

The effectiveness of any deterrent device depends partly upon how well its presence can be concealed. Obviously, any would-be thief who wants your car and knows about the device will try to disarm it. Don't tell even your best friend that you've installed a theft deterrent; people talk.

You may want to install a hood lock, which will not only discourage hot-wiring, but will also prevent disarming the deterrent. Some protection is provided by the circuit itself, should the wires be cut; cutting either of the wires marked CA-CB or BA-BB will remove power from the ignition coil. Unfortunately, if the ignition is hot-wired (by placing a jumper from 12 volts to the ignition coil), the jumper simply bypasses the deterrent, removing the theft protection.

Hugh Wells, W6WTU, 1411 18th Street, Manhattan Beach, California 90266

Obviously you've got to be able to disarm the deterrent to drive your car. An automatic circuit built into the deterrent arms the circuit whenever the engine is started. It's up to you to remember to disarm the deterrent before time-out.

It's better to use a pushbutton rather than a toggle switch, installing it where it can be reached comfortably, conveniently, and inconspicuously, even with passengers in the car. It's best to locate it within arm's length, where one hand can reach it without stretching or making any unusual movement. As far as a thief is concerned, it could even be positioned in the middle of the dashboard — after all, who'd suspect that a "secret" switch would be placed where everyone could see it?

oops!

If you forget to press the disarming button after starting the engine, the circuit will time out, leaving you momentarily stranded and embarrassed. If this happens, just turn the ignition switch on and press the button to start the 20-second recovery process.

Twenty seconds feels like an eternity when you're caught in traffic. (If you're uncomfortable, think how a thief would feel . . . .) But the delay is necessary; you want to prevent the thief — had he found the button and pressed it — from associating the action of pushing the button with disarming the deterrent.

What happens when the car goes back to the dealer or into the shop for service? Somebody else, probably a stranger, will be driving it. One solution is to place a clip lead or small alligator clip across the disarm button contacts. Another would be to place a clip lead across Q4. Either action would disable the deterrent so that service people could drive the car without having to know about the device. (Remember to remove the jumper after service to restore protection.) For shorter periods, such as with valet parking and car washes, you can leave the engine running when you get out. If time-out occurs, you can simply remark that your car is temperamental and that you know how to handle it.

circuit description

A small SCR (Q1), used as a remote disarming latching switch, is "fired" when the disarm button is pressed. Once fired, Q1 keeps the circuit from starting the time-out cycle. A 555 (or 556) is used as a timing mechanism for removing power from the ignition system after time-out. A simple RC time constant provides a time-out delay of approximately 1 minute. A specific time-delay value isn't important, but enough time must be allowed for the car to be driven to a vulnerable location. Any additional time could allow the car to be driven too far from the starting point.

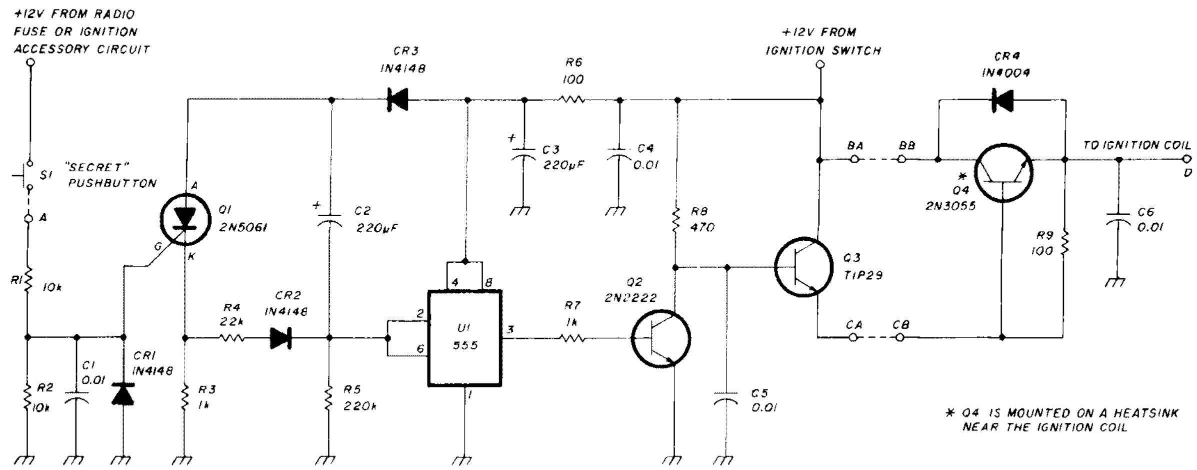


fig. 1. Mobile theft deterrent.

C1,4,5,6	0.01 μF 100-volt disc ceramic
C2,3	220mF 25-volt (RS 272-1017 or RS 272-1029) electolytic
CR1,2,3	1N4148, 1N914, or equivalent signal diode
CR4	1N4004 or equivalent power diode
Q1	2N5061, 2N5062, ECG 5401, or ECG 5402 SCR
Q2	2N2222, 2N4401, ECG 123A, or RS 276-2058 NPN transistor
Q3	TIP 29, TIP 31, ECG 152, or RS 276-2017 NPN power transistor
Q4	2N3055, ECG 181, or RS 276-2041 NPN power transistor
R1,2	10-k, 1/2-watt
R3,7	1-k, 1/2-watt
R4	22-k, 1/2-watt
R5	220-k, 1/2-watt
R6,9	100-ohm, 1/2-watt
R8	470-ohm, 1/2-watt
S1	RS 275-1547 or RS 275-1571 mini SPST momentary pushbutton switch
U1	555 or RS 276-1723 IC timer

The R5 and C2 combination determines the time-out period. Their values have been selected for about the maximum time obtainable when using a low-leakage electrolytic capacitor for C2. Tantalum capacitors are generally not suitable in this application because of their high leakage current.

When power is first applied to the ignition system, pins 2 through 6 of U1 will start out with a logic high of about 11 volts and drift down as capacitor C2 charges through resistor R5. Pin 3 of U1 will remain at a logic low until pins 2 and 6 drop below a threshold voltage value of approximately 4 volts. Then pin 3 will go high, causing the collector of transistor Q2 to go low, turning off the base drive to transistors Q3 and Q4. They, in turn, remove power from the iginition system. In the deterrent, U1 operates as an electronic teeter-totter with a resistor and capacitor combination on pins 2 and 6 for timing. The other end of the teeter-totter is pin 3, which provides output drive. When pins 2 and 6 are high (Q1 fired), pin 3 is low, driving the base of Q2 low. Transistor Q2 operates as an inverter, driving high the bases of transistors Q3 and Q4. Transistors Q3 and Q4 are connected as a Darlington for high gain (H_{FE} above 2000). The high gain is required to hold Q4 in saturation when the base drive is at a logic high. Transistor Q4 functions as a pass transistor/switch for controlling ignition current values up to 7 amps. A 7-amp current capability is sufficient for most ignition systems.

Diodes are used in the circuit to perform various functions. CR1 protects the gate of SCR Q1 from negative voltage spikes. CR2 isolates C2, preventing it from becoming charged through resistors R3 and R4. CR2 and CR3 isolate capacitor C2 from circuit power, allowing C2 to retain its charge status regardless of the presence or absence of circuit power. CR4 protects transistors Q3 and Q4 from reverse voltage spikes generated by ignition coil flyback upon power removal. With CR4 in place, the reverse voltage across the transistors will not exceed 1 volt.

construction

The circuit is divided into two assemblies for mounting convenience. All of the electronic circuitry may be placed in a metal box separate from Q4, which is mounted on a heatsink near the ignition coil. Placing the circuit in a grounded metal box ensures rf protection from high voltage ignition pulses and mobile transmitters. Disc ceramic capacitors are used at the input and output of the circuit to prevent rf from disturbing the SCR and 555 logic states. A screw terminal block may be mounted on the side of the box for wiring connections.

Transistor Q4 requires a heatsink to improve its reliability, even though it operates in saturation. At 7 amps of current flow, about 5 watts of power will be dissipated by Q4. That amount of heat requires a heatsink with a surface area of about 5 square inches and a thickness of 1/8 to 1/4 inch. A heatsink with fins, mounted in line with the engine air flow, will provide

additional cooling. If desired, the amount of heatsink surface may be reduced for currents around 3 amps. However, a generous amount of heatsink material is cheap insurance for long transistor life.

Transistor Q4 must be insulated with a mica washer from the heatsink if the heatsink is to be grounded. All metal burrs must be removed from heatsink holes. Small burrs around the holes will puncture the mica washer (insulator) and ground the transistor. Apply thermal grease to both sides of the mica washer to provide heat transfer from the transistor to the heatsink. A small amount of nonconductive silicon grease makes a suitable thermal conductor.

deterrent placement

Two types of ignition systems are in common use today. Both can be controlled by the theft deterrent as long as the car battery has its negative terminal grounded (the deterrent would have to be redesigned for a positive ground system). The oldest and most common is the standard ignition system, which consists of an ignition coil and a set of breaker points. The second type is an electronic system consisting of an electronic converter, *ignition coil, and a* breakerless timing trigger.

It doesn't matter whether the Q4 heatsink assembly is mounted on the engine, firewall, or fender well, but the assembly should be mounted near the ignition coil power wire.

Avoid long extension wires to keep series resistance to a minimum. Finding the correct wire to intercept or cut is usually fairly easy when only one power wire is routed to the ignition system. Some electronic systems have two large wires routed to the system; one of them provides power from the ignition switch, and is the wire that must be intercepted to insert the Q4 assembly. The second wire is used to provide power from the starter solenoid during starting. It will be left alone.

Standard ignition systems use a resistor or resistance wire in series with the ignition switch and ignition coil to reduce power dissipation in the coil. The Q4 assembly is connected in series with that resistor wire at either the coil terminal or at the resistor terminal. If the resistor can't be located, assume that the connecting wire is also the resistor. Note: *do not cut the resistance wire.*

Mount the electronic circuit box in any convenient location where the box will be grounded. Connect a wire from the ignition switch (+12 volts) to the terminal marked BA (Q3 collector). Connect a wire from terminal BA to terminal BB (Q4 collector). Route a wire to the pushbutton from terminal A (resistor R1), and another wire from terminal CA (emitter of Q3) to terminal CB (base of Q4). Connect terminal D (emitter of Q4) to the ignition coil.

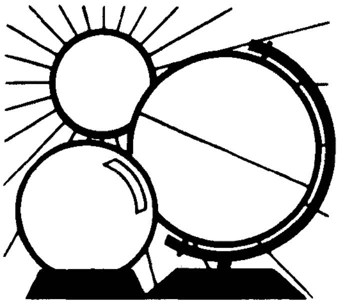
194

for diesels

The theft deterrent may also be used on diesel automobile engines. A warm engine usually starts immediately, providing the thief an opportunity to drive to a street intersection. But cold starts present a challenge, because the "cold" glow plug timing is nearly equal to the deterrent time-out time. A thief might not get the engine started before time-out. In either case, the car won't be driven very far before the engine quits.

To install the deterrent on a diesel engine, locate the electric fuel shut-off valve near the fuel injector pump. There's usually one control wire attached that provides power to operate the valve when the ignition switch is turned on. Connect the Q4 deterrent circuit in series with the control wire. Terminal BA connects to the ignition switch end of the control wire, and terminal D connects to the fuel shut-off valve.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

more DX propagation tips

Last month we discussed weak signal reception in terms of the chart that accompanies this column each month. Numbers shown in the chart represent the highest frequency bands that should be used at specified hours. As a general rule, operate on the highest band available in order to optimize signal strength by minimizing the number of hops through the absorbing D region of the ionosphere.

To fully utilize this optimum propagation mode, the takeoff angle (TOA) of your antenna must be approximately 10 degrees. If the elevation pattern of the antenna doesn't include significant energy at this low angle*, operate on the next lower frequency band but be prepared to pay the price in signal loss, due to the greater number of hops (more hops mean greater loss at the points of reflection/refraction and passage through the D layer). For the shorter paths — for example, Europe to Japan — dropping down to the next lower band raises the TOA required by 12 degrees, but unfortunately means one more hop will be required with an additional loss in signal level of 10 dB. Dropping down two bands nets a TOA 23 degrees higher, one to two more hops, and 24 dB of additional signal loss. Using a lower frequency band on the longer paths accounts for a 4-degree elevation in TOA and a loss of 6 dB for each hop. These longer paths represent five to six maximum-length hops. With this number of long hops and accumulated per-hop absorption, one more hop doesn't make as much difference in the TOA or attenuation, compared to shorter ones.

*Most don't, unless a rather large ground system is used with verticals or the horizontal array is over a wavelength above the earth — Ed.

Knowing your antenna's pattern and using this information, questions of tradeoffs arise. Should I lower frequency to take advantage of my antenna's TOA and lose signal level from more hops, or should I use the antenna on the highest band and be a few dB down from the antenna pattern maximum? If your tradeoff calculations come out about even, consider signal quality parameters (such as stability) rather than available signal strength. Stable signals in frequency, phase, and amplitude over a short time — i.e., seconds or minutes — are needed to "read" the transmitted information.

The length of time needed to decipher the information is a function of the modulation being "read," but in most cases greater stability represents an improvement. This occurs when you operate just below the MUF. As a general rule, for stability, choose a frequency that is just 15 percent below the MUF. If you drop too low in frequency, a form of multipath distortion occurs that sounds like interference. The frequency just below the MUF is the most stable and therefore experiences minimum fading — QSB. Of course, when the geomagnetic field becomes variable, as during a disturbance from a solar wind particle influx, even frequencies near the MUF become more unstable in frequency, phase, and amplitude. After a few years experience or training, DXers can "read" signals having some of these poor characteristics. If you consider these propagation rules and practice learning to "read" the difficult signals, you'll enjoy the experience of rare DX QSOs more often.

last-minute forecast

The higher frequency bands (10-30 meters) are expected to peak the second week of this month. Long-skip openings during periods of higher solar activity and flux should raise the MUFs about 15 to 20 percent over median mid-latitude noontime values. Look for evening transequatorial long-hop openings, especially if the geomagnetic field becomes disturbed as the solar flux drops off toward the end of the week. The lower frequency bands should remain in their winter "finery" during the first and last weeks of the month. Expect geomagnetic (field) disturbances during the middle of the last week.

No significant meteor showers are scheduled to appear in February. A full moon will occur on the 13th, with its perigee on the 25th.

band-to-band summary

Ten and twelve meters, the highest day-only DX bands, are nearest the MUF for southern hemisphere paths. They will be open most days when the solar flux is above 75 during the 7- to 10-hour period centered around local noon. These bands open on paths toward the east and close toward the west. The paths may be as long as 2400 miles in single-hop length, and occasionally twice as long during evening transequatorial openings.

Fifteen and twenty meters, almost always open to the southern part of the world, will be the main daytime DX bands. Twenty should stay open on long southern paths into the night, while 15 will drop out in the afternoon. Total path lengths of from 5000 to 7000 miles are expected on these bands and one-long-hop transequatorial propagation is also possible, favoring evening

FEBRUARY

WESTERN USA

GMT	PST	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
0000	4:00	30	40	20	10	12	10	10	20
0100	5:00	20	40	20	12	12	10	10	20
0200	6:00	20	40	20	15	12	10	10	20
0300	7:00	30	*40*	20	20	12	12	12	20
0400	8:00	40	*40*	30	20	12	15	15	30
0500	9:00	40	*40*	30	20	15	20*	20	30
0600	10:00	40	*40*	*30*	20	20	20	20	40
0700	11:00	40	*40*	*30*	*20*	20	20	20	40
0800	12:00	40	*40*	*30*	*20*	20	20	20	40
0900	1:00	*40*	*40*	*30*	*30*	*20*	20	20	40
1000	2:00	*40*	*40*	*30*	*30*	*20*	*20*	*20*	40
1100	3:00	*40*	*40*	*30*	*30*	*30*	*30*	*30*	40
1200	4:00	*40*	*40*	*30*	*30*	*30*	*30*	*30*	*40*
1300	5:00	*40*	30	15	20	*30*	*30*	*30*	*40*
1400	6:00	*40*	20	12	12	*30*	*30*	*30*	*40*
1500	7:00	40	20	10	12	20	*20*	20	*40*
1600	8:00	40	20	10	12	15	*30*	20	*40*
1700	9:00	40	20	10	10	15	20	20	*40*
1800	10:00	*40*	20	10	10	12	20	*30**	*40*
1900	11:00	*40*	30	10	10	12	15	20	*40*
2000	12:00	*40*	30	12	10	12	12	20	20
2100	1:00	*40*	40	12	10	12	12	15	20
2200	2:00	*40*	40	15	10	12	10	12	20
2300	3:00	*40*	40	20	10	12	10	12	20

MID USA

MST	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)	CST
5:00	30	40	20	12	12	10	10	30	6:00
6:00	30	40	20	12	12	10	12	30	7:00
7:00	20	40	20	15	12	12	12	30	8:00
8:00	30	*40*	20	20	12	15	15	40	9:00
9:00	40	*40*	*30*	20	15	15	15	40	10:00
10:00	*40*	*40*	*30*	20	20	20	20	40	11:00
11:00	*40*	*40*	*30*	20	20	20	20	40	12:00
12:00	*40*	*40*	*30*	*20*	20	20	20	40	1:00
1:00	*40*	*40*	*30*	*20*	*20*	*20*	*30*	40	2:00
2:00	*40*	*40*	*30*	*30*	*20*	*30*	*30*	40	3:00
3:00	*40*	30	*30*	*30*	*20*	*30*	*30*	*40*	4:00
4:00	*40*	20	15	*30*	*20*	*30*	*30*	*40*	5:00
5:00	30	20	12	20	*30*	*30*	*30*	*40*	6:00
6:00	30	20	10	15	*30*	*30*	*30*	*40*	7:00
7:00	30	20	10	15	20	*30*	20	*40*	8:00
6:00	40	20	10	12	20	20	20	*40*	9:00
9:00	40	20	10	12	15	20	20	*40*	10:00
10:00	40	20	10	12	15	20	20	*40*	11:00
11:00	40	20	10	10	15	20	20	*40*	12:00
12:00	*40*	20	10	10	12	15	20	30	1:00
1:00	*40*	30	10	10	12	12	15	30	2:00
2:00	*40*	30	12	10	12	12	15	20	3:00
3:00	*40*	40	12	10	12	12	12	20	4:00
4:00	*40*	40	15	10	12	10	12	20	5:00

EASTERN USA

EST	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean, S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
7:00	*40*	40	20	12	12	12	12	30
8:00	40	40	20	15	12	15	15	30
9:00	40	40	20	20*	15	20	20	40
10:00	40	*40*	*20*	20	20	20	20	40
11:00	40	*40*	*30*	20	20	20	20	40
12:00	40	*40*	*30*	20	20	20	20	40
1:00	*40*	*40*	*30*	*20*	*20*	*30*	*30*	40
2:00	*40*	*40*	*30*	*20*	*20*	*30*	*30*	*40*
3:00	*40*	*40*	*30*	*30*	*20*	*30*	*30*	*40*
4:00	*40*	*40*	*30*	*30*	*30*	*30*	*30*	*40*
5:00	*40*	30	15	*30*	*30*	*30*	*30*	*40*
6:00	30	20	12	20	*30*	*30*	*30*	*40*
7:00	20	20	10	15	20	*30*	*30*	40
8:00	30	20	10	15	20	20	20	40
9:00	30	20	10	12	15	20	20	40
10:00	40	20	10	12	15	20	20	40
11:00	40	20	10	10	15	30*	20	*40*
12:00	40	20	10	10	12	20	20	*40*
1:00	40	20	10	10	12	20	20	*40*
2:00	40	20	10	10	12	15	20	*40*
3:00	*40*	30	12	10	12	12	15	30
4:00	*40*	40	12	10	12	12	12	20
5:00	*40*	40	15	10	12	10	12	20
6:00	*40*	40	20	10	12	10	12	20

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

hours during periods of high solar flux and disturbed geomagnetic field conditions.

Thirty and forty meters are both day and night bands. Intermediate distances (up to 1000 miles) in any direction represent daytime DX. Nightime DX on these bands is expected to exceed those distances encountered on 80 meters and, as on 80, will follow the darkness path across the sky. Reduced midday signal strengths and distances may occur on days of high solar flux values or periods of anomalous absorption.

Eighty and one-sixty meters will exhibit short-skip propagation during the daylight hours and lengthen for DX at dusk. These bands follow darkness, opening to the east just before local sunset, swinging more to the south toward midnight, and ending up in the Pacific areas during the hours before dawn. Except for daytime short-skip signal strengths, high solar flux values hardly affect these bands. On some days, however, the condition known as anomalous absorption will diminish day and night signal strengths. The 160-meter band opens later and ends earlier.

ham radio

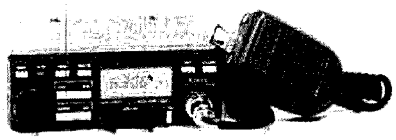
NEW products

ICOM IC-38A 220-MHz mobile

ICOM has announced the IC-38A, a 25-watt, 220-MHz compact mobile that expands ICOM's existing line of IC-28A/H 2-meter and 1C-48A 440-MHz mobiles.

The compact unit measures 5.5 x 2.0 x 6.1 inches, transmits from 220 to 225 MHz, and receives from 215 to 230 MHz. It features 21 memory channels, an internal speaker, and a large LCD readout with automatic dimmer circuit to reduce brightness. Scanning is included; you can scan the entire band or just the memory channels from the HM-12 mic. With only 11 front panel controls, the IC38A is easy to operate.

Options include the IC-HM14 DTMF mic; PS-45 13.8-volt, 8-amp power supply, SP-10 external speaker, HM-16 speaker mic and HS-15/HS-15SB flexible boom mic, and PTT switchbox.



The suggested retail price for the IC-38A is $459.00.

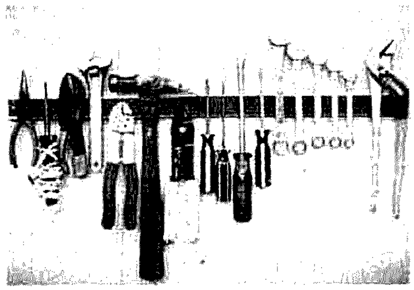
For details, contact ICOM America, Inc., 2380-116 Avenue N.E., Bellevue, Washington 98009-9029.

Circle #311 on Reader Service Card.

magnetic tool racks

Texas Magnetics Corporation — no stranger to Amateur Radio — is celebrating their 10th anniversary. TMC is the largest U.S. supplier of magnetic base assemblies used in the manufacture of mobile antennas. Other "Magna-Grab" products available from TMC include magnetic tool racks, cable and wire routers, fishing tool retrievers, plus permanent magnets and assemblies of all types.

Made of heavy-duty chrome-plated steel, "Magna-Grab" magnetic tool racks come in two sizes: 13 inches (the TMC-100, $12.95 plus $3.50 S&H) and 25 inches (the TMC-200, $18.95 plus $3.50 S&H). No assembly is required; mounting hardware is included.



For information, contact Texas Magnetics Corporation, Special Products Division, Department 100R, 2714 National Circle, Garland, Texas 75041.

Circle #316 on Reader Service Card.

transfer function analysis/synthesis program

BV Engineering has just released XFER, a transfer function analysis and synthesis program that uses short-circuit transfer impedance functions around an operational amplifier to compute circuit element values and circuit configurations which will synthesize a desired transfer function. Conversely, given a circuit configuration and element values, XFER will compute a circuit's transfer function. Multiple stages of short-circuit transfer impedance functions using forward and feedback elements in operational amplifier configurations enable the user to synthesize and analyze most any transfer function having real roots.

Once a circuit or transfer function has been specified, XFER quickly computes the magnitude and phase response, enabling performance of sensitivity and Monte Carlo analysis. Circuit configurations can be viewed on the screen; complete circuit and transfer function editors are built into XFER.

XFER is menu-driven and interactive, with free-format input, and "understands" common engineering abbreviations. Data files generated by XFER are compatible with other BVE software such as SPP, PCPLOT, PDP and TEKCALC. Transfer function files generated by XGER can be used by the SPP program to perform transient and time-domain analysis of user generated waveforms.

XFER is available under the PCDOS and MSDOS operating systems for $72.95 from BV Engineering, 2200 Business Way, Suite 207, Riverside, California 92501.

Circle #312 on Reader Service Card.

AVCOM portable spectrum analyzer

AVCOM's PSA-35A portable spectrum analyzer offers frequency coverages of 10 to 1750 MHz and 3.7 to 4.2 GHz for checking signal strength, inband attenuations, terrestrial interference, filter alignment, faulty connectors, LNA's, feedhorn isolation, and cable loss at all commonly used satellite communication frequencies, including 12 GHz downconverters.

The PSA-35A features a built-in DC block with + 18 VDC for powering LNA's and BDC's with the flip of a switch, calibrated signal amplitude display, and rechargeable internal battery with built in charger. Portable and easy to use in field test situations, the PSA-35A is also suited for applications in research and development or classroom use. The PSA-35A is priced at $1965.00.

For information, contact AVCOM of Virginia Incorporated, 500 Southlake Boulevard, Richmond, Virginia 23236.

Circle #309 on Reader Service Card.

tools and test equipment

A new catalog of tools and test equipment is offered free by Jensen Tools, Inc. Illustrated in full color, the 160-page catalog contains information on more than 1000 items.

Two new sections feature supplies and equipment in support of fiber optics and wire/cable systems. An expanded line of circuit board equipment includes breadboard kits, cutter and drill sets, anti-static carrying cases and racks, test cables, insertion/extraction tools, and many other production tools.

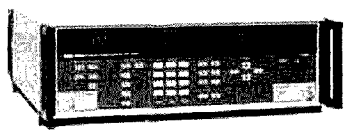
For a free catalog, contact Jensen Tools Inc., 7815 South 46th Street, Phoenix, Arizona 85044.

Circle #314 on Reader Service Card.

new signal generators

John Fluke Manufacturing Company, Inc. has introduced its 6061A Programmable Synthesized Signal Generator, the latest addition to its 6060 signal generator family.

The 6061A's high performance is targeted at rf applications, with increased demands on spectral purity. Residual fm is guaranteed to be less than 6 Hz rms (0.3 to 3 kHz) in the frequency range of 245 to 512 MHz (typically 4 Hz rms), non-harmonic spurious are less than -60 dBc,



NEW products

with -123 dBc typical SSB phase noise at 500 MHz. The 6061A has a frequency range of 0.01 to 1050 MHz with 10 Hz resolution. Amplitude range is from -127 to +13 dBm with 0.1 dB resolution and an absolute accuracy of $\pm$1 dB. Internal and external a-m and fm can be used in combination or separately.

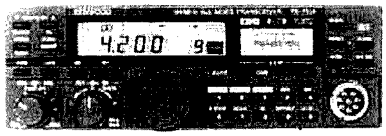
For more information or a demonstration of the Fluke 6061A, write, John Fluke Manufacturing Company, Inc., P.O. Box C9090, Everett, Washington 98206.

Circle #320 on Reader Service Card.

new 2-meter all-mode mobile transceiver

Trio-Kenwood Communications has introduced the TR-751A, an all-new 2-meter, all-mode mobile transceiver. Features include automatic mode selection, many scanning functions, an illuminated LCD display, status lights, and an analog S- and rf meter for easy viewing. The unit puts out 25 watts on high power and 5 watts on adjustable low power.

It covers 142-149 MHz, and can be modified to cover 141-151 MHz (note that a MARS or CAP permit is required to operate on these frequencies). Ten memory channels plus COM channel store frequency, mode, and CTCSS tone offset. Two channels for "odd split" operation are featured, as are all-mode squelch; a noise blanker; RIT; dual, digital VFOs; and semi break-in CW with sidetone. A 16-key DTMF hand microphone and mounting bracket are supplied. Options include a VS-1 voice synthesizer and a front-panel selectable 38-tone CTCSS encoder.



The suggested retail price for the TR-751A is \$599.95. Trio-Kenwood Communications, 1111 West Walnut Street, P.O. Box 7065, Compton, California 90224.

ac power line monitor

The Testware LDM-120 is a very low-cost ac power line disturbance monitor designed to measure and store worst-case ac line voltage variations caused by surges and sags. An LED bar graph display covers from 60 to 160 VAC RMS. Priced at less than \$100, the unit features a built-in audible alarm, an external alarm output, and selectable time constants.

For details, contact Testware Electronic Test Instruments, 4425 Canoga Avenue, Woodland Hills, California 91364.

Circle #319 on Reader Service Card.

computer rotor control interface

The KR-001 computer rotor control interface from Encomm, Inc., gives satellite enthusiasts automatic control of antenna azimuth and elevation. Used with the Kenpro KR-5400A, which provides the electro-mechanical interface to the rotor motors, the KR-001 provides the hardware interface to the computer, converting analog signals to digital for both the elevation and azimuth channels. It also provides the drive signal for driving the motors in the desired direction.

The unit plugs into the cartridge port of the C-64 and operates with tracking software written by N4HY for AMSAT available only from the AMSAT software exchange. Kenpro and Encomm provide the software needed to point the antenna from data entered into the program in real time; tracking software is *not* available from Encomm or Kenpro. Subroutines of the automatic tracking program which apply to the KR-001/KR5400A combination are supplied with the KR-001 for those who wish to write their own tracking software. The suggested retail price is \$149.95.

For information, contact Encomm, Inc., 1506 Capital, Plano, Texas 75074.

Circle #315 on Reader Service Card.

NEW products

changing winds

Though residential-scale wind power is far from being a widely popular energy source, home-generated wind power hasn't disappeared; its following has just gotten smaller. To serve that market, the Thermax Corporation of Burlington, Vermont, manufactures a scaled-down wind generator designed for such modest tasks as charging batteries to supply daily or emergency power to remote cabins, boats, or Amatuer radio equipment.

The Windstream Wind Generator, which stands 20 inches high and weighs only 20 pounds, puts out 12 volts of direct current in an 8-mph wind and has an automatic system that tilts the rotor out of harms's way in strong winds. Priced at $589, the generator won an award from the Department of Energy last year.

For details, contact Thermax, 1 Mill Street, Burlington, Vermont 05401.

Circle #321 on Reader Service Card.

keypad frequency entry

Stone Mountain Engineering has announced the 757 QSYer, a frequency keypad accessory for the Yaesu FT-757GX, which permits the transceiver's operating frequency to be changed to any other frequenccy in the unit's range as often and as rapidly as desired.

The QSYer is a tiny computer terminal that interfaces directly with the 757's accessory jack. It contains its own 8-bit microprocessor, support circuitry, full-size telephone-type keypad, and a sub-miniature speaker which sounds a different tone for each key as it's pressed. The QSTer's all-metal enclosure measures 3.1 x 3.5 x 2 inches, and is color-matched to the 757's finish. The unit installs in seconds — with only two plugs — into the 757's rear panel jacks.

The QSYer is available for $89.50, plus $2.50 shipping and handling. For further information, or to order, contact Stone Mountain Engineering Co., Box 1573, Stone Mountain, Georgia 30086.

Circle #310 on Reader Service Card.

linear power amplifier

The Commander II is a grounded-grid, class AB2 linear power amplifier that operates on the Amateur band. An Eimac 3CX800A7 external anode triode with forced air cooling and modern stripline circuitry insures efficient and conservative operation. Reduced ratio vernier drives on all tuning controls allow smooth, easy tuneup.

Front panel input tuning control allows a higher circuit *Q* for excellent linearity and a very low input SWR to exciter all across the 2-meter band. A built-in automatic delay circuit insures proper cathode conditioning before rf drive can be applied, greatly extending tube life.

With a frequency range of 144-148 MHz (others available), it can be used on USB, LSB, CW, RTTY, fm, and packet. Priced at $988.00 plus shipping, its power requirements are 117/234VAC, with the latter recommended). Rf Drive power is 15 watts nominal, 25 watts with optional relay; rf output is 600 watts, with 15 watts drive.

For complete details, contact C.C.I.Electronics, 104 West Vine Street, Edgerton, Ohio 43517.

Circle #308 on Reader Service Card.

repeater products demo cassette

Advanced Computer Controls, Inc., is pleased to announce that it has a new audio cassette available which describes and demonstrates its repeater control products. Included in the demonstration are the RC-850 and RC-850 Repeater Controllers, the Digital Voice Recorder, and the ITC-32 Intelligent Touch-Tone Control Board.

The cassette is suitable for individual listening or for club meeting presentation. It lets the listeners hear ACC's repeater control products in operation and how users can benefit from using them on their repeaters. The demonstration cassette is available on request at no charge.

ACC manufactures microcomputer based control systems for Amateur Radio, commercial, and government radio users. For additional information, contact Advanced Computer Controls, Inc., 2356 Walsh Avenue, Santa Clara, California 95051.

Circle #318 on Reader Service Card.

NEW products

new Midian catalog

Midian Electronics' new 1987 full-color, 32-page product catalog offers a bright new presentation of its standard tone-signaling products plus an introduction to many new products. Also featured are products from Midian's sister company, Advanced Signaling Technologies, manufacturers of microprocessor-based paging, display, status, and radiotelephone terminals that are system-compatible with Midian's portable and mobile signaling product line. In addition to the listing and description of the product line is a section illustrating the operations of Midian and AST's various departments. Copies are available upon request from Midian Electronics Incorporated, 2302 East 22nd Street, Tucson, Arizona 85713.

Circle #317 on Reader Service Card.

antenna switch

Alpha Delta has announced its new four-position rf switch, the DELTA-4.

Designed to give years of trouble-free use, the DELTA 4 is rated at full Amateur power, 1500 watts. It will ground four antennas not in use or, when an antenna is selected, it will ground the antennas not in use. Lightning surge protection is provided by a field-replaceable ceramic gas tube ARC-PLG cartridge.

The DELTA 4 is designed with both hf and UHF applications in mind. Insertion loss is rated at 0.1 dB at 30 MHz and 0.5 dB at 450 MHz. It's priced at $69.95. For more information, contact Alpha Delta, P.O. Box 571, Centerville, Ohio 45459.

Circle #307 on Reader Service Card.

high-power duplexers

Two new duplexers are available from NCG. The new CF-412 Broad Range Duplexer has a very broad frequency range: 1.3-450 MHz on the low input and 900-1400 MHz on the high frequency side, giving the dual-band operator the same freedom as the VHF/UHF operator enjoys. Maximum power is 70 watts, with isolation more than 39 dB.

The new CF-415 duplexer provides the dual-band operator an extra degree of safety with its high-power capabilities. Most VHF and UHF transceivers develop 45 watts of power; although the old type of duplexers are rated at 50 watts, it has been a common occurrence for them to fail, causing final burnout. The CF-415 safely handles 500 watts on hf, 400 watts on 145 MHz, and 250 watts on 450 MHz. The isolation on both bands is more than 50 dB.

Both the CF-412 and the CF-415 duplexers are available from the manufacturer and through independent dealers. For information, contact NCG Company, 1275 N. Grove Street, Anaheim, California 92806.

Circle #303 on Reader Service Card.

new publication for kit builders

The Heath Company of Benton Harbor, Michigan, has announced the publication of the *Kit Builder's Journal*. Premiering in January, 1987, the bi-monthly *Journal* covers all aspects of building electronic and non-electronic kits — both Heath's and others.

Articles will cover kitbuilding tips, Heathkit news and reviews of products, tips from Heath's technical consultants, and other valuable do-it-yourself information. Subscribers will also be offered special discounts on selected Heath Company products.

For a six-issue subscription, order KBJ-2000-NM and send $9.95 to Heath Company, Box 1288, Benton Harbor, Michigan, 49022.

Circle #306 on Reader Service Card.

continuous coverage receiver

ACE Communications, Inc. has introduced the model AR-2002, a professional grade scanning monitor receiver that covers 25-550 MHz and 800-1300 MHz continuously.

The AR-2002 utilizes latest microprocessor and circuit technology to offer features that include a 20-channel memory scan, priority scan, band search, multi-mode reception, conventional dial tuning, selectable frequency increments, and a bar graph signal strength indicator.

The unit incorporates commercial-type receiver technology such as 750 MHz receiver i-f, a high-level double-balanced mixer, a low-noise wide-band rf amplifier, and a high-stability VCO unit.

The user price for the AR-2002 is $499.00. For further details, contact ACE Communications, Inc., 22511 Aspan Street, Lake Forest (El Toro), California 92630-6321

Circle #304 on Reader Service Card.

basic service kit

Jensen Tools Inc. has developed a new Basic Service Kit for the budget-minded electronic technician. Ideal for field service, in-house maintenance, trade school and personal use, this new addition to Jensen's Telvac economy line contains over 40 hand tools in a solid wood/vinyl case with removable pallets, document pouch, and key-lock latches. Priced at $189, the kit includes standard service tools such as screwdrivers, pliers, nut and hex drivers, punches, wrenches and soldering equipment, as well as a 5-inch hemostat, reverse action tweezer, combination spring tool, wire crimper/stripper, and other specialty items. A choice of test meters is also offered as an optional accessory.

For more information or a free catalog, contact Jensen Tools Inc., 7815 S. 46th Street, Phoenix, Arizona 85044.

Circle #305 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. **Liability** for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H 03048.

COMING EVENTS

Activities — "Places to go . . ."

OHIO: February 15. The Mansfield Mid*Winter Hamfest/Computer Show, Richland County Fairgrounds, Mansfield. Doors open to public 7 AM. Tickets $3.00 advance; $4.00 at the door. Tables $5.00 advance; $6.00 at the door. Forums, Flea Market in large heated buildings. For more information, tickets, tables SASE to Dean Wrasse, KB8MG, 1094 Beal Road, Mansfield, Ohio 44905 or phone (419) 589 2415 after 4 PM EST

OHIO: February 22. The Cuyahoga Falls ARC will sponsor its 33rd annual Auctionfest, Tallmadge High School. Flea Market opens 8 AM. Tables $6.00 advance. Auction begins 11 AM. Admission $4.00 at the door. $3.00 advance. Check in on 147.87/.27 repeater. For more information SASE to Cuyahoga Falls ARC, PO Box 614, Cuyahoga Falls, Ohio 44222.

MICHIGAN: February 22. The 17th annual Livonia ARC's Swap 'n Shop. 8 AM to 4 PM at the Dearborn Civic Center, Dearborn. ARRL/VEC FCC Amateur exams given by the Motor City Radio Club. Plenty of tables, refreshments and free parking. Talk in on 144.75/5.35 and 146.52. For further information SASE to Neil Coffin, WA8GWL, c/o Livonia ARC, PO Box 2111, Livonia, MI 48151.

INDIANA: March 8. The Morgan County Repeater Association's Indiana Hamfest, Indiana State Fairgrounds Pavillion Building, Indianapolis. Admission $5.00 at the door. Open to the public 8 AM. 8' flea market table $8.00. Talk in on 145.25. For table reservations or information SASE before February 25 to Aileen Scales, KC9YA, 3142 Market Place, Bloomington, IN 47401 (812) 339-4446.

OHIO: April 24, 25, 26 DAYTON HAMVENTION

ILLINOIS. March 15. The Sterling-Rock Falls ARS 27th annual Hamfest, Sterling High school Fieldhouse, 1608 Fourth Avenue. Doors open 7:30 AM. Dealers, large flea market and space for self-contained RV's. Concession stand will be available. Tickets $3.00 advance, $4.00 at the door. Commercial tables $5.00 and $3.00. Talk in on 146.25/85 W9MEP. For information, tables or tickets: Sue Peters, PO Box 521, Sterling, IL 61081 or call (815) 625 9262

MASSACHUSETTS: March 1. Annual MTARA Flea Market, K of C Elder Council 69 Hall, Granby Road, Chicopee. General admission $2.00. Spouse and kids free. Tables $10.00 at door. $8.00 advance. Tailgating $5.00. Vendor setup from 7 to 10 AM. Public admitted 10 AM. Food and refreshments. Walk in Amateur license exams 10:30 AM. Talk in on 146.34-146.94 and 52 simplex. Write MTARA, Box 3494, Springfield, MA 01101 or call Bob, WB1EQS (413) 532-4891 days or Mickey, N1COR (413) 562-1027 evenings.

FLORIDA: March 21-22. The Playground Amateur Radio Club's 17th annual North Florida Ham/Swapfest, Shrine Fairgrounds, north Ft. Walton Beach. Doors open 8AM both days. FCC exams Saturday only. ARRL, and QCWA meetings. Banquet Saturday night. RV parking. Talk in on 146.19/.79 and 52. For more information write PARC, PO Box 873, Ft. Walton Beach, FL 32548

NEW YORK: February 15. Long Island ARRL Indoor Hamfest, sponsored by LIMARC, Electricians Hall, 41 Pine Lawn Road, Melville, LI. Doors open 9 AM. Admission $4.00 at the door; $3.25 in advance with SASE. Exhibitors admitted 7 30 AM. For more information call Hank (516) 484 4322 evenings

FLORIDA: March 7. The City of Palms (Fort Myers) annual Hamfest, Moosehall on Parkmeadow Drive. 9 AM to 4 PM Dealers, forums, swap tables, snack bar, luncheon and more. Talk in on 28/88. For information: Harry Arnold, K9ALX, 5414 Brandy Circle SW, Fort Myers, FL 33907 (814) 482-3113.

NEW HAMPSHIRE: March 14. The Interstate Repeater Society of Derry, NH will hold its annual Flea Market, Lions Club Hall, Lions Avenue, Hudson. Doors open 8 AM. Admission $1.00 at the door. Tables $8.00 each. For table reservations (603) 623-0628 or (603) 883 9441. Write I.R.S., PO Box 693, Derry, NH 03038.

NEW YORK: March 1. The Mt. Beacon Amateur Radio Club's first annual Winter Hamfest, State Armory, Newburgh. 8 AM to 3 PM. Doors open for sellers 7 AM. General admission $3.00. Table space $4.00. Reserved tables $5.00. Refreshments available. Talk in on 146 37/.97 and 146.52. For reservations and information: Stan Disbrow, WA2KOY, Mt. beacon ARC, PO Box 841, Wappingers Falls, NY 12590. (914) 876-1659

MINNESOTA: February 21. The Robbinsdale ARC's 6th annual Midwinter Madness Hobby Electronics Show. New site Medina Ballroom, Hwy 55, Medina (western suburb of Mineapolis). Admission $3.00 advance; $4.00 at the door. Flea Market and Retail Exhibits open 8 AM. 8' flea market tables $8.00. FCC exams start 9 AM. Talk in on K0LTC Club Repeater and 146.52 simplex. To register SASE with fees to Robbinsdale ARC, PO Box 22613, Robbinsdale, MN 55422 or call Bob (612) 533-7354. FCC Exam registration. Send completed Form 610, photocopies of current license with $4.00 payable to ARRL VEC to Ron Schulz, NA0U, 6308 Peacedale Avenue, Edina, MN 55424

OPERATING EVENTS

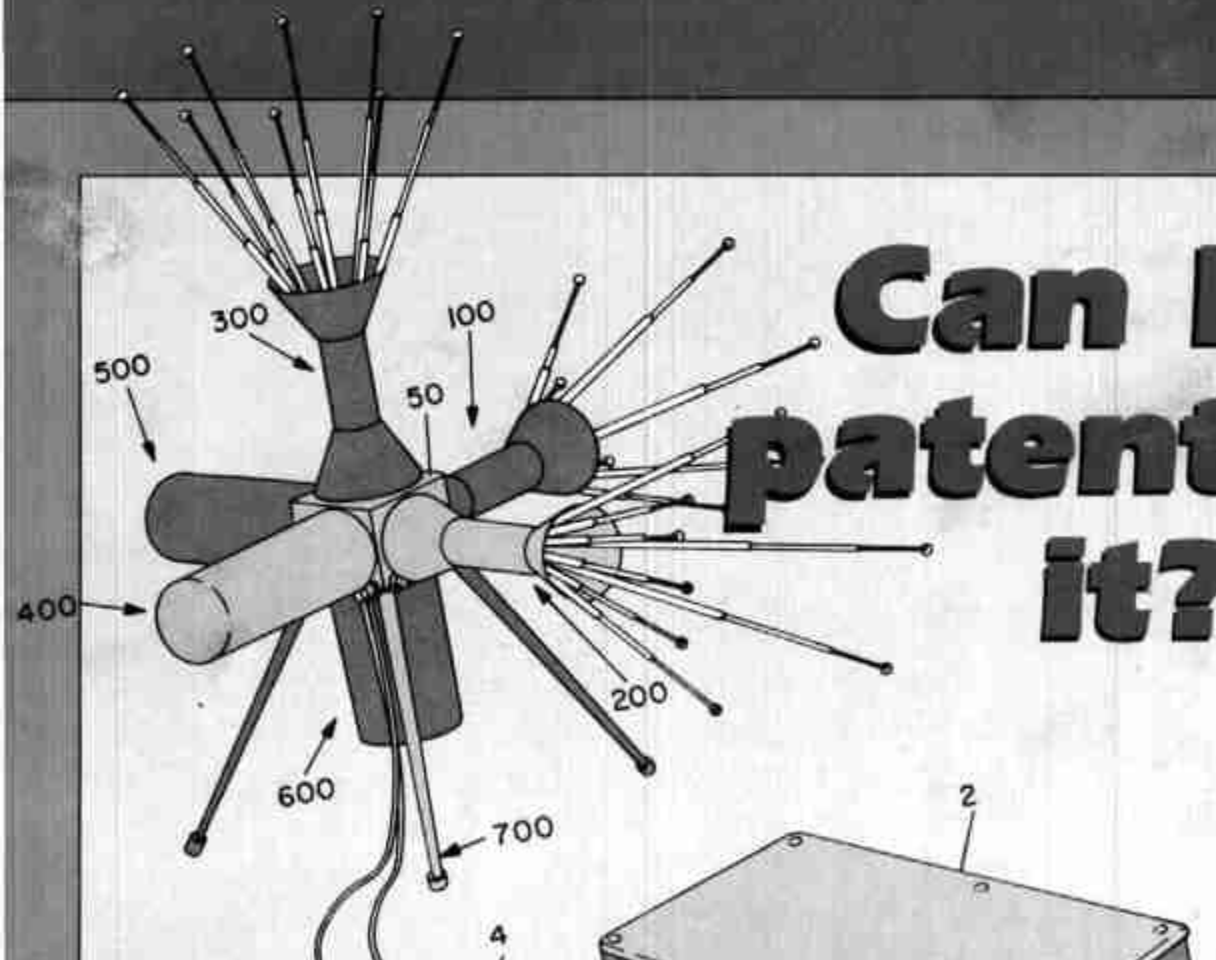
"Things to do . . ."

February 1. 1987 Classic Radio Exchange, 2100 UTC Sunday to 0400 UTC Monday. Exchange name, RST, QTH, receiver and transmitter with other hams interested in restoring, operating and just enjoying older equipment. Send logs, comments, anecdotes, pictures, etc. to Jim Hanlon, W8KGI, 5560 Linworth Road, Columbus, OH 43085. Please include SASE

February 7. 1987 New Hampshire QSO Party sponsored by the NH Amateur Radio Association. 1900Z February 7 to 0700Z February 8. 1400Z February 8 to 0200Z February 9. Send log and comments to Mount Moriah Repeater Society, c/o Bud Valcourt, N1BYQ, 19 Teague Drive, Salem, NH 03079.

MARCH 1987 / $2.50

ham radio magazine



Can I patent it?

hr

focus on communications technology

This month's cover:
Can I patent it?
. . No, *you* can't patent the multi-octave, omnidirectional antenna pictured on the cover, because it's already been patented - by Harold A. Wheeler, a well-known inventor and holder of many patents in electronics and communications, some dating back to the late 1920's. U.S. Patent No. 4,633,265 was issued to Wheeler, with rights assigned to the Hazeltine Corporation of Commack, NY, on December 30, 1986.
Thanks to Harold Wheeler, the Hazeltine Corporation, and Leo Zucker, K2LZ (see "Can I Patent It?") for making these illustrations available.
- Ed.

FCC ANNOUNCES NEW NOVICE PRIVILEGES — SEE PAGE 6

— SEE PAGE 6

ham radio magazine

MARCH 1987

volume 20, number 3

ham radio *magazine* is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00, three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service): one year, $37.00
All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

international subscription agents: page 114

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio* *are available to the blind and physically handicapped* from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to ham radio
Greenville, New Hampshire 03048-0498

contents

REFLECTIONS

manned vs. unmanned space flight

Having recently celebrated the 25th anniversary of the launch of OSCAR I, the world's first non-government orbiting satellite, Amateur Radio has a proud history to look back upon, and an exciting future to anticipate. Our nearly two dozen experimental communications satellites and three manned Ham-In-Space missions have made it possible for thousands worldwide to participate, both personally and vicariously, in space exploration and research. They have also afforded us an unprecedented opportunity to compare the relative value and merits of manned vs. unmanned space missions.

Are the complexity, expense, and risk of manned space exploration justified, and if so, on what grounds? These questions are voiced by the lay public from time to time, either in the wake of a disaster or when appropriations are under consideration. The great strides in space exploration attributable to unmanned space probes raise some valid questions. Couldn't shuttle-type missions be accomplished by unmanned, computerized, robotically controlled machinery? Wouldn't this be cheaper, safer, and easier than providing life support systems? Isn't man, in the final analysis, just so much excess baggage?

A more general question might be: Does the future of the space program lie in manned or unmanned missions? The unmanned craft now in space, and those planned for the foreseeable future, are singular enough in purpose to be controlled by telecommand. Their missions are of long duration and generally one-way; hence volunteer crew members are scarce. The rationale behind unmanned space probes is obvious; that behind manned exploration less so.

The common justifications for a human presence in space fall into three categories: philosophical, political, and technical. "Earth is the cradle of mankind," wrote early rocketry theorist Konstantin Tsiokovsky (1857-1935), "but man cannot live in the cradle forever." We go into space for the same reason we climb mountains, explore caves, and sail the Queen's ships toward the edge of the earth and certain doom; because it is there, and we are who we are. We still rise to a challenge, just as we did in Columbus' day, and the challenges are much the same: propulsion, guidance, and environment. Within the past generation we have met these challenges, to the extent that space travel is now not only possible, but almost routine. But is it advisable?

The politician will consider the military aspects of a manned space presence, and conclude that further progress is inevitable; the only question is whether to lead or to follow. A generation ago President Kennedy said, "The exploration of space will go ahead whether we join it or not. It is one of the great adventures of our time and no nation that expects to be the leader of other nations can stay behind in the race for space."

The United States and the Soviet Union may dominate, but no longer monopolize the quest for space. Japan and the European Space Agency are making great strides not only in their well proven launch capabilities, but in space manufacturing. If the United States is to remain competitive *we must continue to send manned laboratories into space*. The financial and scientific rewards are just around the corner.

The technological imperative for manned space missions becomes obvious when we consider the experiments which have been carried aloft in the cargo bay of the space shuttle, just in the past three years. We have witnessed breakthroughs in space manufacturing and materials processing, as well as astronomy, space plasma physics, life sciences, crystal growing, antenna testing, remote sensing, radar experiments, and of course, Amateur Radio! The launching, retrieving and on-orbit repair of unmanned spacecraft require mission specialists, as well as pilot astronauts to deliver hardware and personnel to the lofty job site.

All that is present technology. In January of 1984 our President directed NASA to begin developing plans toward launching a permanent space station by the end of the decade. Current schedules suggest that fabrication can begin this year, leading to an operational space station between 1992 and 1994. Even allowing for further scheduling delays associated with returning the space shuttle to service, it is clear that the question is not one of *if*, but rather *when*. Already Europe, Canada, and Japan have indicated an intention to participate in a truly international, permanent manned space presence.

There are still those who say manned space missions are too costly, in human life as well as dollars and cents. But by the National Transportation Safety Board's uniform measure of safety — fatalities per hundred thousand miles — space travel shines as the safest transportation mode yet devised! As for financial costs, how can one put a price on progress? The medical breakthroughs alone justify the expense of the whole program. Through electrophoresis, the separating of cells by electricity in microgravity, pharmaceuticals have been manufactured in earth orbit at 700 times the yield and five times the purity of similar processes on earth. Dramatic advances in the treatment of anemia, cancer, diabetes, emphysema, dwarfism, thrombosis, and viral infection are but a few of the tangible results.

We who have been privileged to participate in the Amateur space program, through our OSCARs, RSs, ISKRAs, and now JAS-1 — as well as through the efforts and accomplishments of W5LFL, WØORE, and DPØSL — are in a unique position to appreciate the roles which both manned and unmanned missions will play in a well balanced space program. To whatever extent we can influence national space policy, it behooves us to press for an aggressive space future which avails itself of the relative strengths of both men and machines. It is not only prudent to pursue both avenues of exploration, but essential to the advancement of civilization, and worthy of our financial and patriotic support.

Tedd E. Hankins, AMSAT 19192 and H. Paul Shuch, N6TX, AMSAT LM167

presstop

NOVICES GET 220, 1270 MHz — PLUS SSB AND DIGITAL ON 10 METERS

Novices will soon be eligible for *full privileges* in all emission modes (though with a 25-watt power limit) on as yet unspecified subbands of 220 and 1270, as well as expanded privileges on 10 meters, which will be divided evenly between CW/digital (including packet, RTTY, ASCII, etc.) and SSB/CW. While complete details were not available at presstime — in early February — more information is expected shortly, with the release of the Commission's official report and order. Informed sources predict that the new privileges will take effect in late March or early April, perhaps even before you read this.

In awarding privileges on 220, the FCC reportedly took the Amateur community somewhat by surprise, since it had indicated earlier that 220 would not be a part of the enhanced Novice package because of unresolved conflicts over that band. A strong showing of support for granting 220 privileges to Novices, however, was credited for convincing the FCC of the importance of reserving portions of that band for Novice Amateur use. Though not specified in the FCC's January 30 release, repeater operation is expected to be included among the enhanced privileges.

According to the FCC release, Part 97 will not only be modified to include expanded Novice privileges, but will also provide for the separation of Element 3 of the Amateur Radio examination into Elements 3(A) and 3(B), providing different theory tests for Technicians and Generals. All Technicians licensed before the effective date of the new regulations will be "grandfathered," however, and will not be required to pass the new General theory exam before upgrading.

All existing Novices will likewise be "grandfathered" and will be allowed to operate on the new bands without passing the new, more demanding Novice exam, which will be expanded to include questions pertaining to operation on the newly-awarded bands. While current Novice examinations may be supervised by only one licensed Amateur, Novice exams occurring after the effective date of the new privileges will be supervised by two examiners. The FCC has specifically recommended that current Novice operators, who were authorized the new privileges without additional qualifications, become knowledgeable in the new requirements before using their new privileges.

According to the FCC release, the expansion of Novice privileges will be implemented in order to attract more Novice operators to the Amateur service without diminishing their incentive to upgrade to higher license classes. FCC Private Radio Bureau Chief Mike Fitch was quoted as saying, "I am delighted with the Commission's actions. I believe the new operating privileges on the 0.23, 1.25, and 10-meter bands will attract new people to Amateur Radio and keep their interest in the hobby by encouraging upgrades. We've provided these new growth tools to Amateur Radio. It's now up to the Amateur community to put the tools to work."

ham radio

can I patent it?

Some patent law basics for the industrious Amateur

Although Amateurs often express interest in obtaining patent protection for some circuit, antenna, or other device which they've conceived, they may not have sufficient understanding of the patent process to protect their inventions adequately.

In this article, we'll discuss what makes an invention patentable. We'll examine a typical patent application, timing limitations, and employee agreements covering inventions created on the job.

what is a patent?

Article I, Section 8 of the United States Constitution authorizes Congress to "promote the Progress of Science . . . by securing for limited Times to . . . Inventors exclusive Right to their . . . Discoveries" — in short, to grant patents. While the constitutional directive would appear to offer virtually unlimited protection, it's important to note that the owner of a patent has the right only to exclude others from making, using, or selling the patented invention in the United States without license by the owner. The patent grant does not confer an absolute right to produce or market the invention free of infringement claims by another who holds a so-called "dominant" or broader patent (more on this later).

The bulk of legislation dealing with patents comes under Title 35 of the United States Code (35 U.S.C.), as enacted in 1952 and amended to date. The federal agency authorized to examine applications and issue patents is the Patent and Trademark Office (PTO) of the United States Department of Commerce.* The PTO's *Rules of Practice*[1] deal with specific requirements for patent applications, procedures to be followed while applications are pending, and payment of maintenance fees for issued patents.

The PTO issues utility patents, patents for new varieties of asexually reproduceable plants, and patents for ornamental designs of articles of manufacture. Utility patents are of potentially greatest interest to Amateurs because they're granted to those who invent or discover "...any new and useful process, machine, manufacture or composition of matter, or any new and useful improvement thereof."[2] These patents are granted for 17 years from date of issue, but may lapse after 4, 8, or 12 years if maintenance fees are not paid in a timely manner.

In electronics, utility patents were granted last year for items ranging in sophistication from, for example, an electric cord holder to nuclear magnetic resonance (NMR) methods and apparatus. While it isn't necessary to furnish a model or prototype of the invention with a patent application, the PTO does reserve the right to require one. So if you've conceived of a device that consumes less energy than it produces — i.e., a "perpetual motion" machine — be sure to have a working model on hand. The patent examiner will certainly want to see it.

To be worthy of a patent, the subject of a utility patent application must be more than just new and useful. It must also have been "non-obvious" to one of ordinary skill in the pertinent art when the invention

*Address: Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Leo Zucker, K2LZ, 34 South Broadway, White Plains, New York 10601

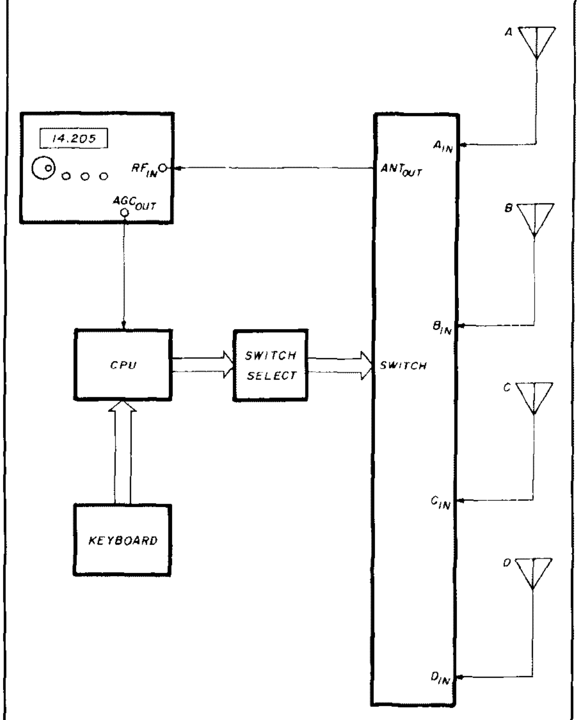


fig. 1. Optimum antenna select system.

was made.[3] The "non-obviousness" criterion is determined initially during PTO proceedings on an application, usually by an evaluation of two or more prior patents or publications which together show all the elements of the claimed invention. If, in the examiner's judgment, it would have been obvious to a skilled worker to combine the disclosures of the references so as to give rise to the invention, your claims will be rejected.

A word of caution: if you're making or selling an article for which a patent is pending, you may use terms such as "patent pending" on the article or in advertising to dissuade others from risking an infringement suit should a patent ultimately be issued. The false use of "patent pending" or similar phrases, however, subjects the perpetrator to a maximum $500 fine for each offense.

what to do before applying

Let's say you're trying to develop a system that will automatically select from four different antennas the one antenna that will provide optimum signal strength while a signal is tuned on your receiver. You've searched the available literature and found nothing. You sit down and sketch out a system as shown in **fig. 1**.

Even before trying out the system, *sign and date your sketch* and have a witness who understands it countersign the sketch. Properly signed and dated sketches — preferably on sequentially numbered pages of a hardbound notebook — can be used as valuable evidence of the date of your invention.

You may then try to assemble all necessary parts for your system and determine operating parameters such as the following: the antenna sampling time and protocol; the necessary increase in receiver AGC level a sampled antenna must provide over a previously switched-in antenna, for the sampled antenna to be switched on line; and the time period over which a switched-in antenna will be held on line prior to initiating the next sampling routine. You may allow the operating parameters to be set in a microprocessor CPU by an input device such as a keyboard and create a program for enabling the CPU to carry out all operating functions.

When your system performs exactly as you planned, make sure you properly record the *successful* test in your notebook, with all components correctly identified. By doing this, you've established a so-called "reduction to practice" of your invention, evidence of which may also be valuable at a later time.

It isn't necessary to have actually reduced your invention to practice before applying for a patent, however. Once you've conceived your system (for example, as shown in **fig. 1**), and determined what you believe to be all other details a skilled worker would need to make and use your system in the best way you know, you may consider filing a patent application.

At this point it's wise to consider obtaining guidance from a patent attorney or agent. A roster of attorneys and agents registered to practice before the PTO is available from the Superintendent of Documents, Washington, D.C. 20402. You should, of course, feel satisfied that a particular individual has the technical background and experience to portray your invention adequately in a formal application if you decide to have him or her represent you before the PTO.

the search

Your attorney will probably advise that a search be conducted before formal papers are filed with the PTO. The cost of a search is often many times less than the total cost — including drawings and filing fee — of preparing formal application papers. It typically takes about two weeks to conduct a search and obtain the results.

The search should be directed to cover all important aspects of your invention. Frequently, an invention disclosure may encompass more than one patentable invention, and a professional search will uncover references pertinent to every aspect of your invention that might qualify for a patent. Two or more

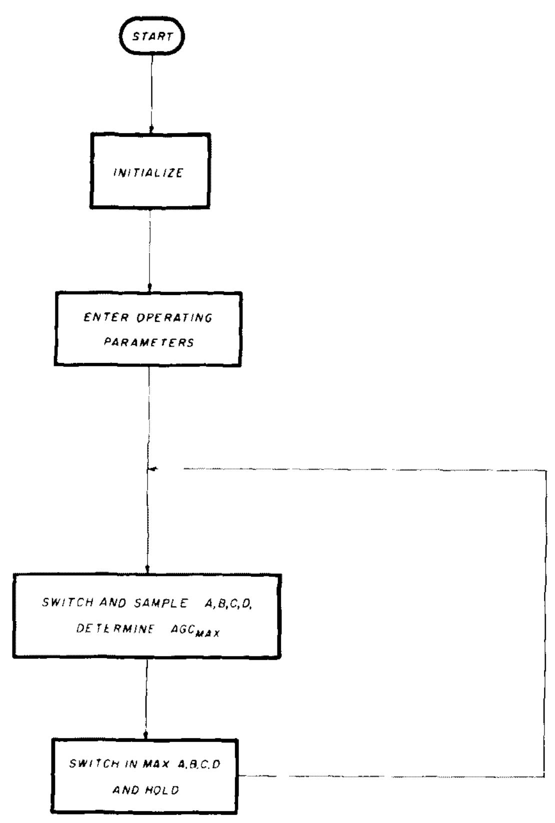


fig. 2. System operation flow chart.

patents sometimes stem from a single "parent" application.

Even if the results are discouraging, you'll get a good idea of how your invention stacks up against the state of the art. If you later conceive of certain additions or improvements to your invention which are not suggested or "obvious" over the references found in the search, you may then give serious thought to obtaining patent protection for the later version.

A patent search can be beneficial in other ways. Remember that even if your invention is eventually patented, it could still infringe upon an enforceable patent of broader scope. Such dominant patents often turn up in the search, and you will at least be forewarned of their existence at an early stage.

the application

If all systems are "go," you'll want to have a formal application prepared and filed with diligence at the PTO. Although the process of examining an application and issuing a patent, if warranted, takes time, there's now a definite trend toward shortening the traditional wait between filing and final disposition. Furthermore, both the applicant and his or her attorney now must inform the PTO of all information they know "which is material to the examination of the application or else face strict sanctions.[4] Such information includes those patents found during prior searches, and thus can be of great help and save time for the examiner who conducts the search at the PTO.

A complete patent application includes a written description of the invention sufficient to enable one skilled in the pertinent art to make and use it; one or more claims delineating the scope of the invention described; a drawing of one or more figures if necessary; an oath or declaration by the applicant stating, *inter alia*, that he or she believes himself or herself to be the original and first inventor of the claimed subject matter; and the required filing fee.

Using the automatic antenna select system proposed in **fig. 1** as an example, your notebook entries will provide a good basis for the written description. If you've arrived at one or more variations of the original configuration you think would enhance the system construction or performance, these alternative "embodiments" must be specified as well. The description must be adequate to enable a skilled worker to make and use the invention you're claiming.

The claim(s) of invention must particularly point out and distinctly claim those aspects of the system you regard as your invention. Depending on what your search uncovered, you may feel you're entitled to relatively broad, intermediate, or only narrow protection. Each claim generally must read as a single sentence. In cases where the invention itself is believed quite narrow, just one claim having very specific terminology may occupy two or more pages of the application papers.

A drawing showing at least the overall system as shown in **fig. 1** would facilitate the drafting of the written description, which can make frequent reference to the illustrated system components while explaining their structure and operation.

Once completed, your application should be filed promptly with the PTO along with the prescribed oath and filing fee. If all formal requirements are met, it will be accorded an official filing date and serial number, and then routed to a patent examiner for further action.

Don't forget to disclose to the PTO all material references of which you're aware. You can do this by filing a separate statement with your application papers or shortly thereafter.

what about software?

You may have taken considerable time and effort to create working system software and wonder if it alone can be protected by a patent. Insofar as software is only a list of instructions addressed to and performed by a computer to bring about a certain result, a patent is generally not available for software, per se.

You may, however, apply to register your software with the Copyright Office at the Library of Congress, Washington, D.C. 20559. For further information, call or write the Copyright Office and ask for Circular No. R61, "Copyright Registration for Computer Programs."

Since your software enables your system (**fig. 1**) to operate as you intended, a flow chart such as shown in **fig. 2**, depicting the system operation when properly programmed, is a worthwhile, possibly even essential addition to your original application disclosure. A full listing of your program need not be included with your written description, as long as a skilled programmer could arrive at a working program without undue difficulty by referring to your written description and drawings.

some important time limits

As mentioned, it's important to move swiftly once you decide you've conceived of a patentable invention. Suspension of pre-filing development work for a long time without good cause can amount to an "abandonment" on your part. The result — if another person conceives the same invention and acts without delay to file an application, he or she may be the one entitled to any patent which may be issued.

If your invention was patented or described in a printed publication anywhere in the world more than a year before your application filing date in the United States, you'll be barred from obtaining a patent here. You'll also be barred if the invention was in public use or on sale in the United States more than one year prior to your filing date.[5] For example, if an article describing *all* essential details of your automatic antenna selection system appears in a magazine published in Japan on January 1, 1987 — and you believe you're the original inventor — you have only until January 1, 1988, to apply for a patent in the United States.

Another example: suppose your antenna selection system works so well you decide to manufacture a large quantity and offer it for sale through an advertisement in the January 1, 1987, issue of *ham radio*. Your deadline for filing a United States application (assuming no prior disclosures) is January 1, 1988.

Although you may disclose your invention publicly up to one year before filing an application in the United States, it's sometimes necessary to file before publicly announcing or commercially exploiting your invention. One example is when you wish to file corresponding applications in certain other countries where "absolute novelty" requirements exist for patent applications. That is, the patent laws of some countries do not allow public disclosure of an invention anywhere in the world prior to filing an application with their governments. Because other time bars may exist, in your case, consult your patent attorney or agent prior to filing.

employment agreements

Amateurs who work in technical capacities for others may be required, as a condition of employment, to execute a written agreement to assign all inventions they develop while on the job to their employer. Without such a written agreement, the employer could not claim title to any patents obtained by the employee independently. The employer would derive only a "shop right" or royalty-free license to use the patented invention.

Because the employee agreements are generally upheld if contested in court, employees who are subject to them should review them carefully before applying for patents on their own. Sometimes an employer will release an invention after an employee discloses the invention and the employer decides not to pursue a patent. Upon obtaining such a release, the employee is then free to apply for a patent — at his or her own expense.

conclusion

The patent system is an integral part of our nation's commercial activity and growth. To foster and reward inventiveness, the framers of our Constitution empowered the owner of a patent with the right to exclude others, for a limited time, from making, using, or selling the claimed invention in the United States. Before obtaining this right, however, the patent applicant must describe the invention in a manner sufficient to enable others skilled in the relevant art to make and use it.

Individual inventors and small businesses play a prominent role in advancing the state of the art in many high technology fields. To encourage this initiative, the PTO reduces by 50 percent its patent filing, processing, and maintenance fees for applications filed only in the interests of individual inventors and small businesses (i.e., those with 500 or fewer employees).

The next time you conceive a new circuit, system, antenna, or any other useful device or process — and feel you can exploit it on your own — consider conducting a professional search. You just might have the makings of a patentable invention.

references

1. Title 37, Code of Federal Regulations (37 C.F.R.).
2. 35 U.S.C. Sec. 101.
3. 35 U.S.C. Sec. 103.
4. 37 C.F.R. Sec. 1.56.
5. 35 U.S.C. Sec. 102.

Leo Zucker, a patent attorney, welcomes inquiries from readers and suggestions for future articles.

ham radio

modular transmit and receive converters for 902 MHz

MMICs make inexpensive building blocks for new band circuits

This article describes a set of up- and downconverters for the 902-MHz band. When used together with the local oscillator chain described previously,[1] the result is a set of building blocks which can form the core of a complete 902-MHz transverter. The converters have a common board design for simplicity; MMIC amplifiers are used throughout, and the filtering is designed for ease in tuning.

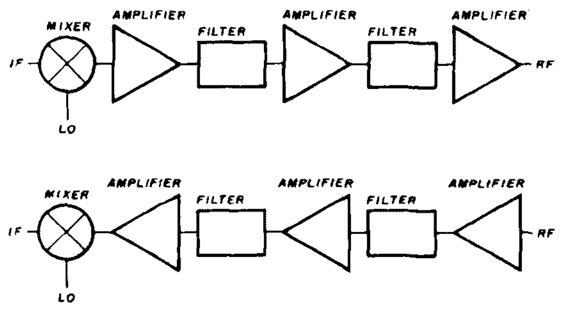


fig. 1. Block diagrams of the converters. The upconverter (top) and the downconverter (bottom) differ only in the direction of the signal flow.

The block diagrams of the up- and downconverter are shown in **fig. 1**. The similarity between the two is immediately apparent. The mixer and the two bandpass filters are identical in each converter, and only the direction of signal flow is changed by reversing the MMIC amplifiers. The two bandpass filters in each are used to provide selectivity, for the amplifier stages are inherently broadband.

With these converters, a 902-MHz transverter is easily assembled. A power amplifier hybrid, such as those discussed by Reisert[2] and Hilliard,[3] can be driven directly from the upconverter module. A low-noise amplifier, such as the one described by Hilliard[4] can be used ahead of the downconverter for critical small-signal work; the converter board alone will provide sufficient sensitivity for local QSOs.

design goals

These converters were designed to achieve several goals which were not met in some of my earlier designs. First, the converter printed circuit board (PCB)

Jerry Hinshaw, N6JH, 142 Kensington Place, Frederick, Maryland 21701

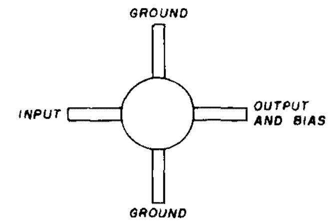


fig. 2. MMIC device typical outline. The various MMIC amplifiers all have the same pin configuration, though the package dimensions vary somewhat.

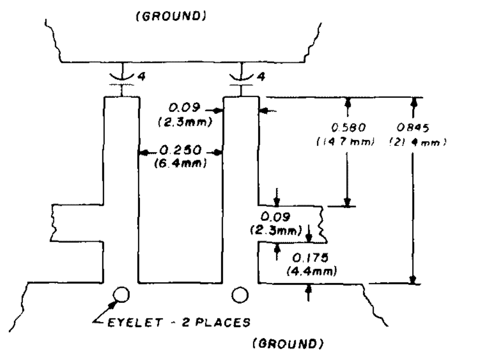


fig. 3. Details of the 903 MHz filter. The dimensions shown are for 1/16 inch G-10 board with a ground plane on the far side.

is common to both the up- and downconverter to simplify fabrication. The physical size of each PCB is small, and a standardized outline was planned from the start to simplify packaging. The converters were designed to be non-critical so that tuning with simple equipment is possible. All circuitry operates from a single 13.6-volt dc supply. Finally, no very costly components are used. There are two configurations of a single circuit card: one is for the receiving downconverter and the second for the transmitting upconverter. For receiving, the main considerations are noise figure and intermodulation distortion, while the transmitting converter should have good spectral purity and sufficient output to drive a final amplifier. These different requirements dictate the selection of different amplifiers, but the same filtering is used for both converters. Before we leap into the "how-to" construction hints, however, a brief review of the amplifiers, filters, and the PCB itself should be helpful.

MMICs

Both converters use silicon microwave monolithic integrated circuits (MMICs) extensively. These devices have been described recently in Amateur publications.[5,6] Each MMIC device is a completely matched broadband rf circuit, so only blocking capacitors and a bias network are needed to make a 50-ohm amplifier. These "building block" amplifiers are a great aid in the design of UHF equipment; at last it can truly be said that gain is cheap.

Among the MMIC amplifier devices suitable for use in this converter are the Avantek MSA series, the CGY-40 device from Siemens, and the newly announced MMIC from Mini-Circuits Labs, the MAR-1.[7] Each of these devices is somewhat different, but they are all similar enough mechanically so that any one of them can be installed on the circuit board for this converter. Only the bias resistor value needs to be changed to adapt to a different MMIC. **Table 1** lists some MMICs, their principle characteristics, and the value of the bias resistor for 13.6-volt operation.

Most of the MMIC amplifiers are available in small, four-lead plastic pill-type packages, while the CGY-40 is available only in a ceramic package. In all cases, two of the leads are grounds and the other two are input and output. Bias is applied through the output lead. Their typical outline is shown in **fig. 3**. Since the package is symmetrical, the device can be simply reversed (and the bias connection moved to the output) to "turn around" the signal flow in a circuit. This idea is central to the re-use of circuitry in this transverter.

filters

The filters used in both the up- and downconverters are identical, although the filtering requirements in the two converters are not exactly the same. In the downconverter, filtering is used to screen the mixer from noise at the image frequency and to help prevent intermodulation distortion by attenuating out-of-band signals. The filtering also helps to prevent the mixer local oscillator (LO) signal from reradiating (out the antenna port), although the reverse isolation of the preamplifiers may well be sufficient to block it. In the upconverter, however, the filters must prevent the LO signal from reaching the antenna through the forward path of the amplifiers. The LO signal must not be permitted to saturate the amplifier chain. In general, these different requirements would result in different filter designs, but it is possible, if not optimal, to use one design.

The filters used here are of edge-coupled design, and are similar to combline filters. Filters of this type have been built on microstrip circuitry before and used with good results by Amateurs.[8,9] Their chief advantage lies in their ease of reproduction and stability; because the inductors are printed onto the board they

need no adjustment. Here, the main variations on this old theme are that the filter layout was optimized using computer-aided design (CAD) software, and that the filtering is distributed. The use of CAD helps to design a good filter, one which comes close to its specifications the first time. By distributing the filter-

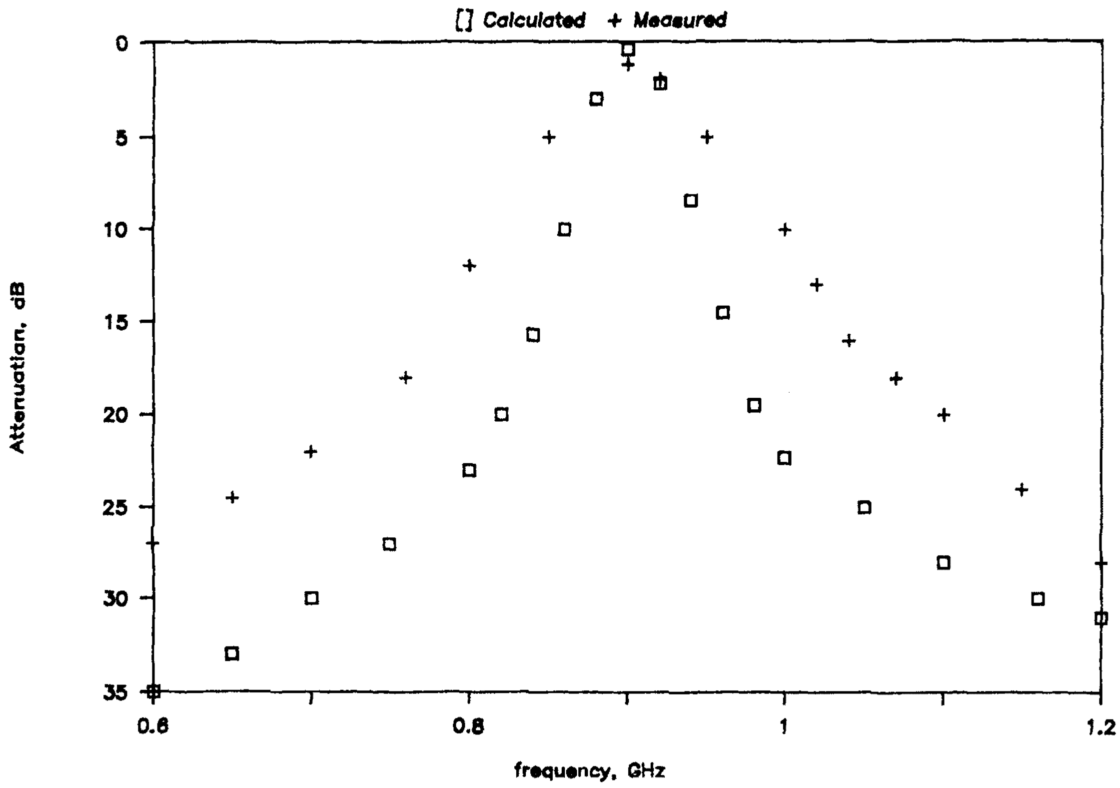


fig. 4. Frequency response of the 903-MHz filter. Both the calculated response (squares) and the measured response (crosses) of a prototype are shown.

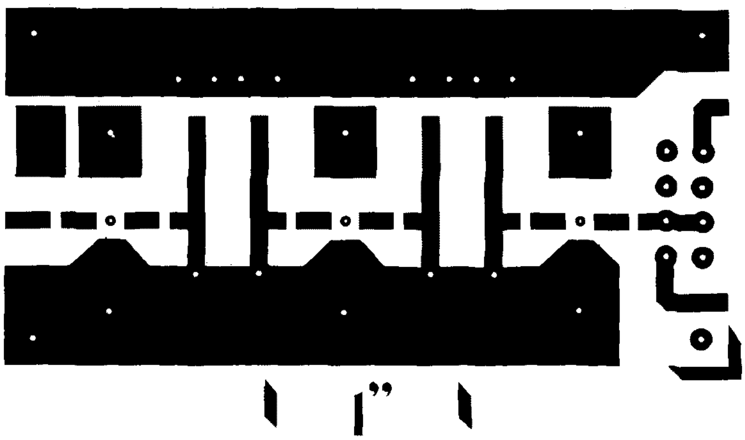


fig. 5. Full-size printed circuit board negative.

ing, the required rejection of out-of-band products is achieved not in one filter, but in two or more. There is a simple reason for this: it is easier to tune two independent filters with few elements than it is to tune one filter which has many resonators. This is especially true when simple test equipment (i.e., no spectrum

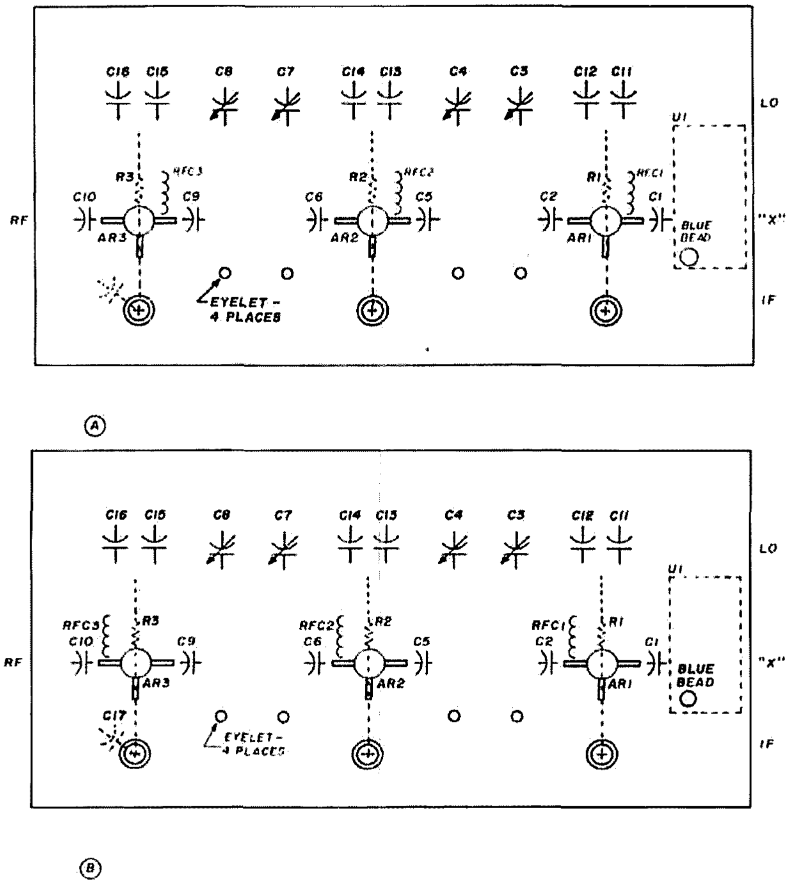


fig. 6. Parts placement: (A) downconverter, (B) upconverter. Parts shown in dotted lines are installed on the other side of the board. Eyelets are used in four places to ensure good grounding for the filters.

Table 1. Typical 900 MHz performance of three different manufacturers' MMIC's.

Device	Typical gain, dB	Typical Noise figure dB	Typical P1dB dBm	Bias volts/mA	Bias Resistor 13.6 volts	Package & Lead Identification
Avantek:						
MSA0104	17	5	+1	4.5/17	560	Plastic package:
MSA0204	13	6	+3	5/25	510	moulded "bump"
MSA0304	12	6	+8	5/35	270	near output lead.
MSA0404	8	6	+11	5.5/50	160	
Siemens:						
CGY-40	9	3	+17	4.5/65	130	Ceramic package. Output lead slashed.
Mini-Circuits:						
MAR-1	14	5	+1	7/20	330	Plastic package. Input lead slashed.

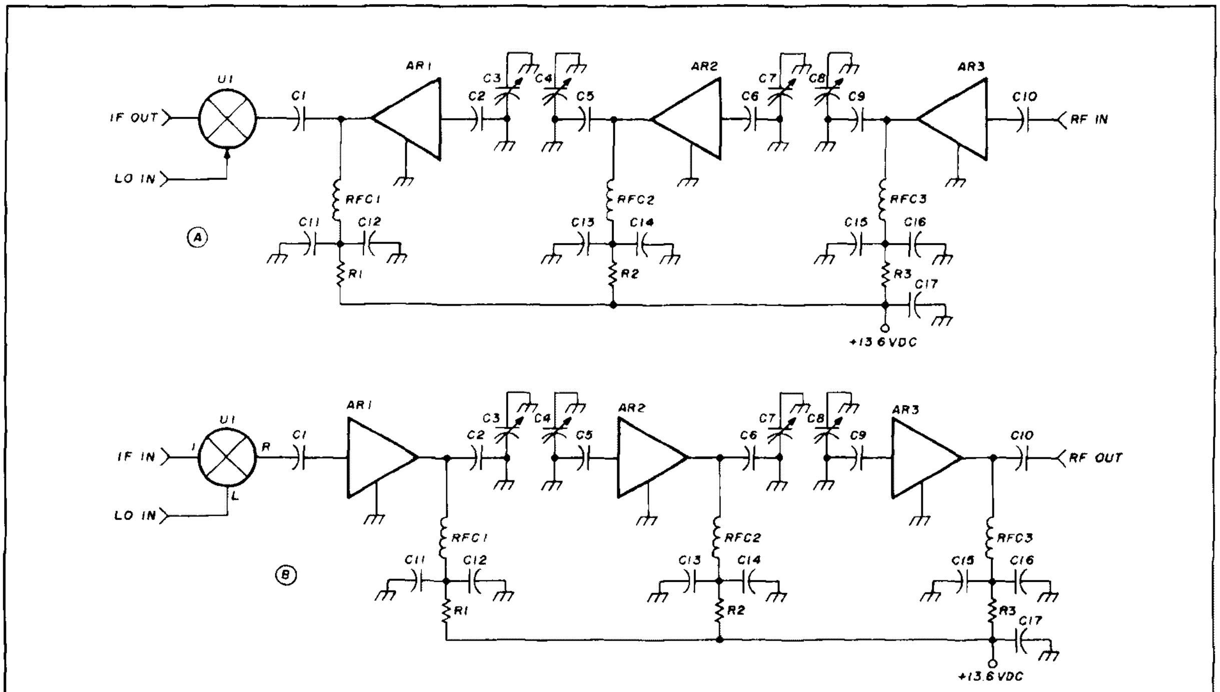


fig. 7. Schematic diagrams: (A) downconverter, (B) upconverter.

analyzer) is used.

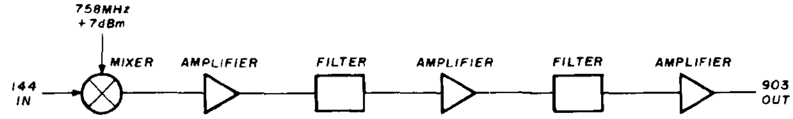
Therefore, a pair of two-section filters is used in each converter. The two filters are separated by an amplifier stage which prevents interaction and consequently improves out-of-band rejection.

Each filter consists of a pair of broadside coupled microstrip transmission lines. Each line is shorted to ground at one end and capacitively loaded at the open-circuited end. A top view of this structure is shown in **fig. 4**. Signals are coupled in and out of the filters by transmission lines which "tap" the resonators at a point whose location helps determine the filter's passband impedance match. The variables in the filter design include the width, length, and spacing of the lines, the loading capacitance, and the location of the tap points. The CAD program juggled these variables to produce a good compromise between insertion loss, rejection, and in-band VSWR. The circuit model presumed typical losses in G-10 type PCB material. Note that the coupling between the filters is, according to the model, entirely between the lines. The tuning capacitors at the ends of the lines are presumed by the software model to be dimensionless. In practice, however, the capacitors tend to increase the coupling between the two resonator sections, increasing the bandwidth and reducing the out-of-band rejection relative to the model. No attempt was made to model the capacitors' non-ideal behavior because there are so many different types of capacitors, and each would require its own analysis.

Figure 5 shows the filter frequency response with a dual plot. The points are the predicted performance of a single filter, while the crosses show actual results from a hand-cut prototype. This prototype used small tubular trimmer capacitors similar to those used in the downconverter. Note that the calculated response is considerably sharper than the actual results, which show the expected overcoupled behavior. This deviation from theoretical performance is often seen in handmade prototypes, where the fabrication accuracy is poor. The performance could probably be improved by using capacitors which are physically smaller, and which therefore produce less stray coupling. Further refinement would be made by carefully etching a precision filter design onto good microwave substrate material. However, this is an amateur design, and it is just this sort of expected inaccuracy which led to the design approach of using non-critical filters. *Non-critical filters tuned to the center frequency are better than sharp filters on the wrong frequency.* The rejection of the converter depends on the cascade of two filters. With two of these filters cascaded, as on the PCB, the out-of-band rejection is approximately twice that of a single filter.

printed circuit board

The board is common fiberglass epoxy G-10 material, 0.06 inch thick. The top traces are shown in the



DEVICE		SBL-IX	MSA03	BPF	MSA04	BPF	CGY-40
STAGE GAIN, dB AT MHz	144	−20	12	−40	8	−40	9
	758	−20	12	−20	8	−20	9
	903	−7	12	−2	8	−2	9

SIGNAL LEVELS, dBm AT MHz								
	144	0	−20	−8	−48	−40	−80	−71
	758	–	−13	−1	−21	−12	−32	−23
	903	–	−7	+5	+3	+11	+9	+18

fig. 8. Signal level diagram for the upconverter. The three main frequencies of interest are tracked through the chain to ensure that each is at a manageable level at each stage.

Parts list, fig. 8

Parts common to both versions

C1,2,5,6,9,10, 11,13,15	30 to 100 pF chip capacitor
C3,4,7,8	2-10 pF variable cap
C12,14,16	0.01 to 1 μF ceramic disk capacitor, 25 volts
C17	5-100 μF electrolytic or tantalum
RFC 1,2,3	Approximately 10 turns No. 30 AWG solid Kynar insulated wire (wire-wrap wire), close-wound on 0.06-inch diameter form (removed after winding)
U1	SBL-1X mixer, Mini Circuits Labs

Parts specific to upconverter:

AR1	Avantek MSA0304 MMIC amplifier
AR2	Avantek MSA0404 MMIC amplifier
AR3	Siemens CGY-40 MMIC amplifier
R1	270 ohms, 1/2-Watt
R2	160 ohms, 1/2-Watt
R3	130 ohms, 1 Watt

Parts specific to downconverter:

AR1,2	Avantek MSA0304 MMIC amplifier
AR3	Siemens CGY-40 MMIC amplifier
R1,2	270 ohms, 1/2-Watt
R3	130 ohms, 1 Watt

full-size negative (**fig. 6**). The bottom side, visible in the photograph, is unbroken copper that serves as a ground plane for the microstriplines. Components are mounted mainly on the top of the board, and soldered to the top traces. Where good grounds are essential, such as at the bases of the filter stubs, eyelets are used to connect top and bottom grounds. The edge of the board was wrapped with copper foil and soldered on both sides to further decrease ground impedances.

A few components — including the mixer, whose can is soldered to the ground plane, and the bias resistors — are mounted on the bottom side. Remember to clear away the copper where non-grounded leads pass through the board. There are four pins on the mixer which must be isolated above ground, and each end of the bias resistors also must be so isolated. There is no artwork for the ground plane side of the board, so the clearance holes are made by hand with a small drill or pad cutter. A pad cutter can also be used to make a pad for the bias resistor on the microstrip side of the board, if desired.

The MMICs are mounted in a hole drilled through the board. One of the two ground leads on each package is soldered to the top ground. The second ground lead is bent at a right angle to the package, inserted through the hole, and soldered to the bottom ground plane. The clearance hole size depends on the device used, because the MMICs listed in **fig. 2** range in diameter from 0.07 to 0.19 inches.

There are two component layout drawings, one for the upconverter and the second for the downconverter. These are both shown in **fig. 7**. Note that the bias inductor is routed to the output end of the MMIC, so the locations of the three coils are somewhat different for the two versions. The MMIC orientations are of course opposite in the two versions. Otherwise, the parts locations are identical.

the downconverter

The schematic diagram of the receiving version is shown in **fig. 8**. The downconverter should have good noise performance, moderate gain, and good selectivity. Recall that the intent of this converter is not to produce the lowest possible noise figure. If a very low noise figure system is needed, a preamplifier should be used.

The input signal from a low-noise amplifier, or directly from an antenna, is fed to the first amplifier in the chain. There are a number of possible choices for this first amplifier stage. Any of the listed devices

could be used, but in general an amplifier with a low noise figure is used at the front end. The CGY-40 is a good choice here because it combines relatively low noise figure with good power handling ability, so that the overall dynamic range is excellent. The main drawback of this MMIC is that it is more expensive than some of the others. (A discrete bipolar or FET transistor stage could also be installed as the first amplifier in the chain.) The board layout includes a rectangular pad near the input for use of base or gate biasing circuitry, if needed.

The first filter stage follows the first MMIC. After filtering, the next amplifier is used mainly as a buffer between the two filters and adds a bit of gain. Lower-cost silicon MMICs are a good choice here; I used the Avantek MSA0304. At first glance it may seem strange that the input stage should have a higher intercept point than the following stage, but the reasoning is this: the second stage has the benefit of filtering to screen strong out-of-band signals, while the broadband input stage must face the world of large signals "naked," as it were. This reasoning is not theoretically rigorous, but in practice it seems to be correct — even a moderately selective filter in front of a preamplifier works wonders in reducing intermodulation spurious responses.

A second filter and a third amplifier follow. The final amplifier provides a good broadband termination for the mixer, which helps to preserve the mixer's low intermodulation distortion. If there is too much gain in the system, such as might be the case when a high-gain preamplifier is used with this converter, the middle stage could be replaced with a resistive pi attenuator pad to isolate the two filters somewhat.

The PCB is laid out for a specific mixer, the Mini-Circuits SBL-1X. This low-cost mixer, which provides good performance up to 1000 MHz, can be used with any i-f of 5 to 500 MHz. The local oscillator drive level is 5 milliwatts (+7 dBm). Other mixers can physically be plugged into the same eight-pin layout, but take care; the SBL-1X has an unusual pin assignment.

When the downconverter is configured as shown in the schematic, it will have a noise figure of 3 to 4 dB at room temperature. It will have good selectivity; the gain at 700 MHz, for example, will be more than 20 dB, down from its gain at 903 MHz (which is +17 dB). The image response at 613 MHz (the 758 MHz LO minus the 144 MHz i-f) measured more than 50 dB below the desired 903-MHz response.** The selectivity of this cascade of two broad filters is sufficient to keep most fm broadcast, TV, and other signals below UHF from causing any problems with 903-MHz reception.

**Measured with the rf drive level set to -35 dBm and with +10 dBm drive at 758 at the LO port.

fig. 9. Photograph of the circuit side of the converter, which in this case is a downconverter version.

the upconverter

The upconverter has a somewhat different task than the downconverter. Here, noise figure is not of great importance, but the output level should be high enough to drive an amplifier. In this case, I wanted 30 to 40 milliwatts output so that a hybrid amplifier would be fully driven to its 7-watt output. This requirement dictated a different choice of amplifier MMICs than did the receiver converter. **Figure 9** is a matrix of the required signal levels. This matrix was put together to ensure that the various signals which exit the mixer do not saturate the amplifier chain, and that the undesired signals are ultimately well attenuated at the converter's output. Thus, the three main signals of note are tracked through the chain. As an example, the 758-MHz LO drive leaks through the mixer somewhat, and appears at the output of the mixer as an undesired spurious at about -13 dBm maximum. This spurious must be attenuated before it reaches the output. The chart shows that the undesired signals remain within manageable range throughout the upconverter chain, and that the expected signal levels are within the linear power limits of each MMIC.

This chart also shows that the desired drive level at 144 MHz is about 1 milliwatt (0 dBm). The drive from the i-f source must not be much greater than 10 milliwatts, and should never be greater than 100 milliwatts or the mixer may be damaged. To adjust the output power of the upconverter, change the input drive level.

The schematic of the upconverter is given in **fig. 8**. The desired 903-MHz signal, mixed from 144 and 758, continues to be amplified throughout the chain, and by the time it reaches the output it is considerably stronger than the next larger signal at 758 MHz. At the ouput, a power level of +16 dBm is achieved, easily enough to drive a hybrid amplifier to its full output.

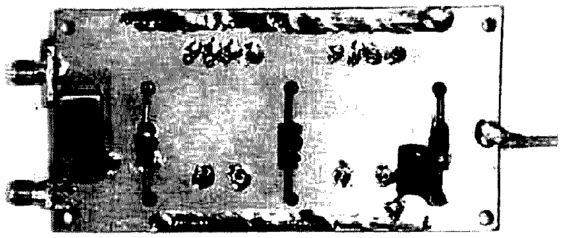


fig. 10. Photograph of the groundplane side of the converter. The mixer and the three MMIC bias resistors are visible.

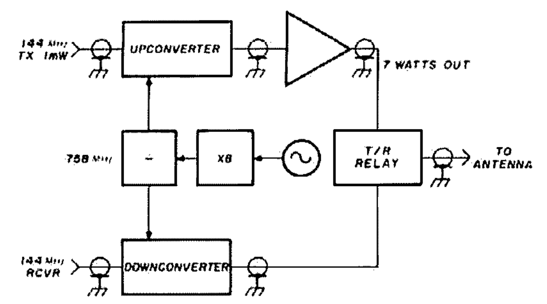


fig. 11. Block diagram of a complete 903 MHz transverter using the two converter boards. As shown, the transverter has 7 watts output and a 3 dB receiver noise figure.

tuning

Once a converter is assembled, it is necessary to tune the filters. No other part of the circuitry requires tuning, fortunately. The filters must be peaked for minimum loss at the center frequency. Once peaked at 903 MHz, for instance, the converter should work well enough over the entire 902 to 928 MHz band. The 3-dB bandwidth of the converter is about 50 MHz. I found that there was only one peak reading obtainable, so that there is no problem with tuning to the wrong harmonic as long as you are measuring the correct frequency. The board can be tested at 903 MHz with all of the components except the mixer installed. A test connector is temporarily installed at the point marked "x" on the layout drawing (**fig. 7**). The other end of the converter board is connected normally as either the drive input (downconverter version) or the output (upconverter).

After tuning and testing at 903, install the mixer. Test the entire converter by applying a low-level signal to the input, the LO to the L port of the mixer, and verify that the output signal is no more than about 10 dB lower than the straight-through gain was before the mixer loss was added. The alignment is then complete.

A number of these converter boards have been built, and none has shown any tuning difficulties. See **figs. 10** and **11**. The filters tune with a single peak, and there have been no instabilities with the MMIC amplifiers. They thus appear to be simple, well-behaved conversion blocks, useful in many applications. The filters' center frequency can in fact be tuned (simply by adjusting the end loading capacitors) over a fairly wide bandwidth, so that these boards could probably be operated anywhere between about 750 and 1000 MHz with only slightly degraded selectivity. Clearly, if the filters' coupled microstrip line lengths were scaled, this range could be further extended. The mixer's operating range is guaranteed only up to 1 GHz, but one was tried at 1300 MHz and showed good conversion loss and isolation.

A complete block diagram of a 903 transverter is shown in **fig. 12**. This transverter uses the two converter boards described here. One converter drives a hybrid amplifier module to 7 watts output in Class C operation, and the receiving converter is used alone with a low-noise MMIC to give a system noise figure of about 3 dB. The entire transverter operates from a single 13.6-volt supply.

sources of parts

The parts should be available from a number of sources. Small capacitors and connectors are listed in a few companies' advertisements in the Amateur press. Although manufacturers are sometimes unwilling to sell single devices, MMICs are available from manufacturers and their distributors in moderate quantities. MMICs will probably be stocked by Amateur vendors soon, too. As a courtesy to Amateur builders, I can supply the pc boards and a few of the other parts for this project. Send an SASE to me for a list of available items.

references

1. Jerry Hinshaw, N6JH, "MMIC Multiplier Chains," *ham radio*, February, 1986, page 72.
2. Joe Reisert, W1JR, "VHF/UHF World," *ham radio*, April, 1986, page 83.
3. D. Hilliard, W0PW, "A CW Transmitter for 902 MHz," *QST*, March, 1986, page 32.
4. D. Hilliard, W0PW, "A 902 to 144 MHz Receive Converter," *QST*, October, 1985, page 21.
5. Bob Atkins, "Microwave Amplifiers," *QST*, January, 1986, page 78.
6. Jerry Hinshaw, N6JH, "Monolithic rf Amplifiers," *ham radio*, March, 1986, page 22.
7. Mini-Circuits, "A 99-cent Monolithic DC to 1000 MHz Amplifier". *Microwave Journal*, August, 1986, page 131.
8. H. Paul Shuch, N6TX, "Improved Grounding for the Microstrip Filter," *ham radio*, August, 1978, page 60.
9. L. Young, "Microwave Filters Using Parallel Coupled Lines," Artech House, Dedham, Massachusetts, 1972.

ham radio

the TEXNET packet-switching network

part 1: system definition and design

Four-node digipeater system reduces congestion, speeds packet delivery

In response to the phenomenal growth of packet radio over the past three years, many packet repeater ("digipeater") networks have been developed, allowing packet communications to be extended over many hundreds, even thousands, of miles. The operation of these digipeater systems has not been without some significant problems, however; most notably, congestion and difficulty in maintaining connections through more than about four or five individual repeaters, with excessive time delays between endpoints.

In an effort to resolve these problems, we decided to establish a rapid, reliable network that would allow Texas packet radio operators to communicate effectively over distances of several hundred miles *in real time*. We now have TEXNET, a four-node network with some of the communication trunks between nodes operating at 9600 bits per second.

In developing TEXNET, our goal was to minimize the cost of building a network node, yet provide very small transmission delay time between users. After the system was in place, we added additional services to the network without degrading the quick response time.

digipeaters — pro and con

A digipeater repeats what is transmitted to it; it can't remember anything about what it is repeating.

A good analogy to a "string" of individual digipeaters is a bucket-brigade line at a fire, in which *each person* is handed a bucket, which he or she in turn hands down the line to the next person. Eventually, each bucket makes it to the last person in the line, who throws the water onto the fire. With digipeaters, the system works like this: the first person in the line fills up a bucket and hands it to the second person. The second person hands it to the third, and so on until it reaches the end of the line (the receiver). Utilizing digipeaters, the sender must wait until the bucket is delivered to the receiver, emptied, and then sent backwards up the line back to the sender, who fills it up again. In other words, *there's only one bucket!*

Just as water can leak or spill from the bucket each time it's passed in the bucket brigade, data packets can be lost at each digipeater. Thus, it's not at all certain that all of the packets will arrive at their appointed destination.

On packet radio we use a layer 2 protocol called AX.25 to assure that all the packets get to the destination in the right order, without any getting lost along the way. This protocol is no more than a set of rules upon which the sender and receiver have agreed; one of the rules is that the receiver will "acknowledge" packets when they're received. The receiver sends these acknowledgments ("ACK," for short) backwards up the bucket-brigade line (i.e., the string of digipeaters) to the sender. If the sender doesn't see an acknowledgment within a few seconds, it assumes that the packet was lost somewhere and retransmits the packet. When the ACK is received, the sender transmits the next packet. However, only one bucket can be put into the line at a time; the ACK must come back from the receiver before the next packet can be started. Notice that none of the digipeaters really get involved in what's going on; they merely repeat the packets. This method of acknowledgment is known as *end-to-end acknowledgment* — that is, the acknowledgment travels all the way through the string of digipeaters from the packet receiver back to the packet sender. (AX.25 is really a little more complicated than this, but it's a good approximation of what's happening.)

Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5EG, Texas Packet Radio Society, 265 Daniel Drive, Plano, Texas 75074

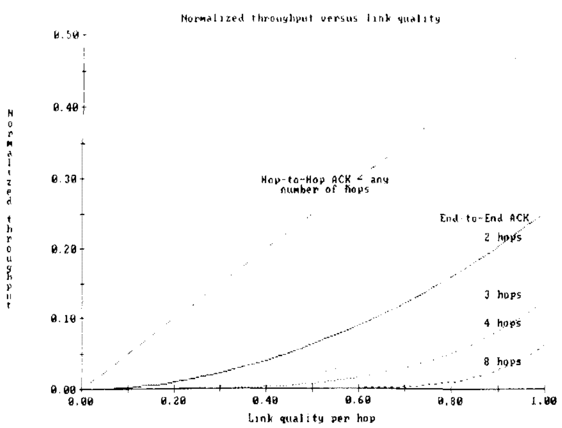


fig. 1. Throughput vs. rf link quality end-to-end and hop-to-hop methods. This graph shows the relative throughput for several packet repeating strategies. The throughput for hop-to-hop acknowledgments is independent of the number of hops, while the throughput for end-to-end acknowledgments degrades with an increasing number of hops. Both strategies degrade (i.e., the throughput is reduced) as the quality of the packet links becomes worse and causes more retries.

As anyone who's used a string of digipeaters to communicate with another station can attest, AX.25 works. But because we have only one bucket, the throughput (the amount of water that can be delivered to the fire) is very limited, and the greater the number of digipeaters in the path, the worse the problem becomes. In fact, it gets *much* worse *very* fast. Since the loss of a packet or of an acknowledgment at any point in the path will cause the retransmission of a packet, the probability of both the packet and the acknowledgment making the round trip successfully quickly becomes very small. This means that communicating a single packet will require many retransmissions, so throughput is reduced significantly.

A better method of relaying the information along a network would be to have each repeater along the way check the validity of the information before passing it on to the next repeater. That is, each repeater would ask for a "fill" of the message before sending it down the line. When the sender is assured that the first repeater received the packet, it could immediately send the next packet into the bucket-brigade line. Thus, we would have a bucket-brigade line with many buckets. Once the first bucket is delivered to the first repeater, another bucket would be filled and delivered to the first repeater by the sender. Thus the throughput (amount of water delivered) would be increased greatly. If we were to employ this strategy in relaying a message, the chance of losing packets grows only slightly larger as the number of digipeaters is increased. This method is called *hop-to-hop acknowledgment*, as each packet is acknowledged between adjacent repeaters before being sent along the network. As the probability of losing a packet grows, the necessity of retransmitting it increases — that is, fewer packets per unit of time can be transmitted. **Figure 1** compares the throughput for hop-to-hop and end-to-end ACK methods to the rf path quality between each repeater.

Response time — the amount of time it takes for a message to be delivered from the sender to the receiver, and for the sender to receive the ACK — is an additional consideration. **Figure 2** compares the round-trip response time for hop-to-hop and end-to-end ACK methods to the rf link quality between each repeater. As can be seen, if the repeaters operate virtually error-free, then the end-to-end acknowledgment strategy works very well. However, if the quality is degraded even slightly, it can be seen that the end-to-end strategy behaves poorly, whereas the hop-to-hop acknowledgment degrades linearly only with path quality. It should be noted that 2-meter packet users consider a path with 75 percent reliability extremely good!

A second problem with any string of digipeaters lies in determining just where a problem exists. If one of the repeaters in the string isn't receiving packets at all, then the sender and receiver know only that the path is "blocked" and are unable to tell where the packets aren't being relayed.

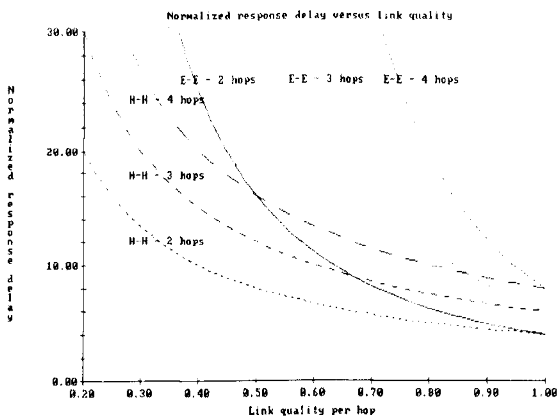


fig. 2. Response time vs. rf link quality end-to-end and hop-to-hop methods. This graph shows the relative response delay for several packet repeating strategies. The response delay for hop-to-hop acknowledgments is shorter (faster response) than for end-to-end acknowledgments unless the rf links are perfect (quality = 1.0), when the two have equal performance. Both strategies degrade (i.e., the response slows down) as the quality of the packet links degrades and causes more retries.

a network solution

To try and solve some of these problems, we wanted to build a packet network that would acknowledge packets at each step on the path, operate with minimal time delay, and provide us with information about the network: specifically, a measurement of the path quality at each point in the network and clear indication of where the break in the path has occurred, should one of the paths be out or one of the nodes be broken. It could also provide other features, such as conference bridges between any three or more users, or bulletin board service to several users simultaneously.

Earlier we stated that AX.25 would provide only end-to-end acknowledgments. This is because X.25 (from which AX.25 was derived) was designed basically as a point-to-point protocol. As a result, it works very well when Station A wants to communicate reliably with Station B. Our network, however, must use some additional strategies (protocols) for managing things like supervision (altering routing tables, reinitializing nodes), error recovery (to indicate where network has failed), and hop-to-hop acknowledgments.

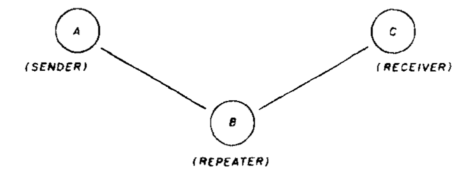


fig. 3. This is a map of a simple network. Station A is sending packets to station C through an intermediate repeater (station B) because stations A and C are too far apart to communicate directly.

It's at this point that we'll break up the problem of communicating between two stations into several "pieces," each of which will have the responsibility of solving only a part of the total problem. If we're smart about how to divide up the problem, each piece will be a fairly straightforward design problem, and each piece will know what to expect of the other pieces. That is, each of the pieces will cooperate with the others in order to solve the entire communication problem. This approach is called "layering" a problem.

layered protocols

Let's look at the problem of communicating a message along a network. Station A is the sender, Station B is the repeater, and Station C is the receiver (see **fig. 3**). The sender, Station A, needs a way to send information along the route A-B-C.

The first problem is to make sure that the information gets from A to B accurately. Let us assign this problem to layer 2 (ignoring layer 1 for now). That is, layer 2 must get information from A to B in the correct sequence, without duplicating any packets and without losing any packets. AX.25 works just fine for this job. Getting data from A to B is a point-to-point problem; A sends the packets and B acknowledges them. Now that some packets have traversed from A to B, how does B know what to do with them? This is a job for the next layer of the protocol, layer 3. Layer 3 tells each node where the information is going; if B is unable to send the information to C (or a path that leads to C), then it informs A that something is

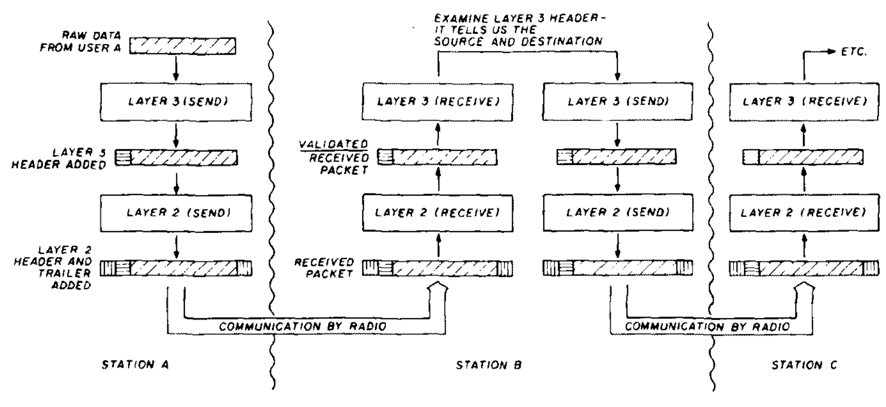


fig. 4. Layering the protocols (wrapping and unwrapping). Each node contains software to wrap the layer 3 and then the layer 2 information around the data. Each node also contains software to unwrap layer 2 and layer 3 information from the data, and examine this information to determine how to route the data to the final receiver.

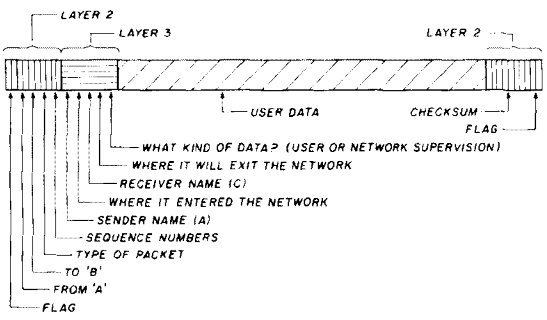


fig. 5. Contents of the packet. The layer 3 envelope is wrapped around the data first. It tells each node where the data came from, and where it is going, and the network entry and exit points. The layer 2 envelope is wrapped around the layer 3 envelope, and tells two adjacent nodes how to exchange the information reliably between themselves.

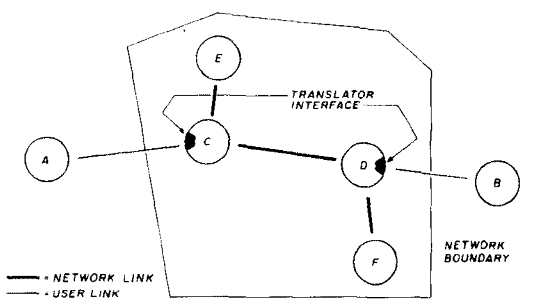


fig. 6. Drawing the network boundaries—which nodes translate from AX.25 to TEXNET-IP. In order for network users not to have to understand the internal network protocol, each network node has a user entry point, which supplies an English-language interface between the user and the network. The user may ask the network for services via this interface.

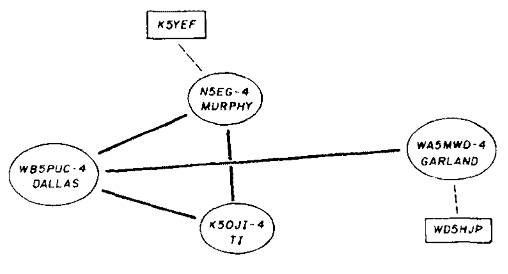


fig. 7. This is a map of the TEXNET test bed and two user stations (operators, TNCs, and 2-meter radios) of the network. Network trunks exist between Murphy, Dallas, and TI, but Garland can only communicate with Dallas.

wrong with the network. So Station A has to add a little additional information at the front of each packet that tells the intermediate stations where the information came from and where it's going.

Let's examine the sequence of events that occurs here. In **fig. 4**, Station A generates some data and sends it to its own layer 3 box. This box adds some information to the data packet (who the sender and receiver are, for example). Then the layer 3 box gives this slightly larger packet to the layer 2 box, which in turn adds a little information to it (things like a checksum for detecting errors, and the callsigns of Stations A and B). Layer 2 at Station A then assures that this packet is reliably delivered to the layer 2 box at Station B. The layer 2 box at Station B, happy with this packet, "unwraps" the layer 2 information and delivers what's left to the layer 3 box at Station B. The layer 3 box at Station B now looks at the information that the layer 3 box at Station A added to the packet and decides what to do with the packet. Probably Station B will determine the best way to get to Station C, and will tell its own layer 2 to send this packet to Station C; Station B will not alter the layer 3 information that station A put on the packet. Then the layer 2 box at Station B will add information (like a checksum, and the callsigns of Stations B and C) to the packet, and reliably deliver it to Station C. The "unwrapping" (examination of the layer 3 header, and the "rewrapping" of the layer 2 data) will continue at each node until the packet arrives at C. At Station C, the layer 2 box will "unwrap" the layer 2 data and then present the remainder to the layer 3 process, which will notice that this packet is destined for this station. Then the layer 3 box at Station C will remove the layer 3 information and present the raw data to the receiver at Station C. The contents of this individual packet is shown in **fig. 5**.

Thus raw data has traversed the network from A to B, through intervening users. At each step of the way it was error-checked and reliably exchanged by adjacent nodes, and each node decided how to route the information along to the final destination. Thus we have built a method that offers hop-to-hop acknowledgment, routing information reliably between two points. It also returns error messages to the sender, since it knows who the sender and receiver are.

There are two important points to consider: a standard protocol (AX.25) has been used at layer 2, and some of the more distressing problems with digipeaters have been solved. Unfortunately, we've added the requirement that the sender and receiver, Stations A and B, understand and implement an additional protocol, the layer 3 box. Rather than require this, we can instead build a "translation" function into Stations C,

D, E, and F. These would converse with A and with B in an English language-like manner, and would make all the decisions about to and from whom packets should be delivered. Thus if Stations A and B can wrap and unwrap the layer 2 information from each packet, and if the human operators at Stations A and B understand the English language commands that C through F need in order to translate and add layer 3 information to each packet, then the users at A and B need only to possess a TNC that has a layer 2 function that is compatible with AX.25 (see **fig. 6**). Fortunately, all TNCs are capable of this.

the TEXNET implementation

This is how TEXNET operates. A user connects to TEXNET just as anyone with a TNC would connect to any station. For example, let's look at the sequence K5YEF (in Plano) would follow to utilize the network to talk to a station in Garland (see **fig. 7**).

In this case, K5YEF is located near the Murphy node, and WD5HJP is located near the Garland node. Notice that the network node stations are not normal TNCs, but are TEXNET network nodes instead.

What K5YEF types is shown underlined; all other text appears on his CRT.

```
CMD>C N5EG-4
CMD>***CONNECTED TO N5EG-4

N5EG-4 VIRTUAL CONNECTION 03 AT 17:04:57 ON 11/26/86

   ***  WELCOME TO TEXNET      V0706-WB5PUC  ***

COMMAND ? Circuit WD5HJP @ GARLAND
YOUR CONNECTION IS ESTABLISHED
```

From this point on, the communication proceeds normally.

What does the station WD5HJP see? Let's take a look at WD5HJP's CRT.

```
CMD>***CONNECTED TO WA5MWD-4
INCOMING TEXNET CONNECTION FROM K5YEF-0 AT MURPHY
```

At this point, whatever K5YEF has typed appears on the screen.

The users of TEXNET connect to it on 145.05 MHz, at 1200 Baud using their standard TNCs. The network communicates between its own nodes using AX.25 as the layer 2 protocol and TEXNET-IP as the layer 3 protocol. The network nodes run their inter-nodal trunks at 9600 Baud on either 220 or 450 MHz, or can run them at 1200 Baud on 2 meters.

It would be best if the users of this network (Stations A and B, for example) had a way to communicate with the network that didn't require the use of human operators and English language commands. Then computers (at A and B) could control setting-up and tearing-dowr connections through the network. Unfortunately, this type of layer 3 protocol — outside the network — requires that all TNCs be standardized for a layer 3 communication process, and no standards now exist in the Amateur community for this function.

The TEXNET-IP layer 3 protocol is "hidden" from all the users because the entry and exit nodes of the network translate the instructions from the users from English to TEXNET-IP and back again. The TEXNET-IP is utilized only within the network, and it is of a family of network protocols known as "datagram" (that is, each packet carries all of the information needed by

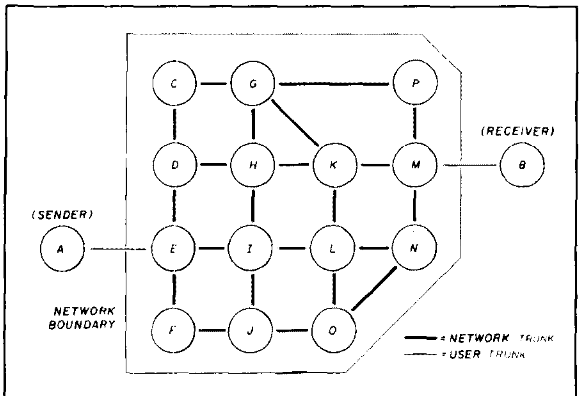


fig. 8. A Mesh network topology. Many paths through this network are possible, AEILNMB, AEDHKMB, AEIHKMB are 3 possible routes. This network is resistant to failures, but expensive to implement.

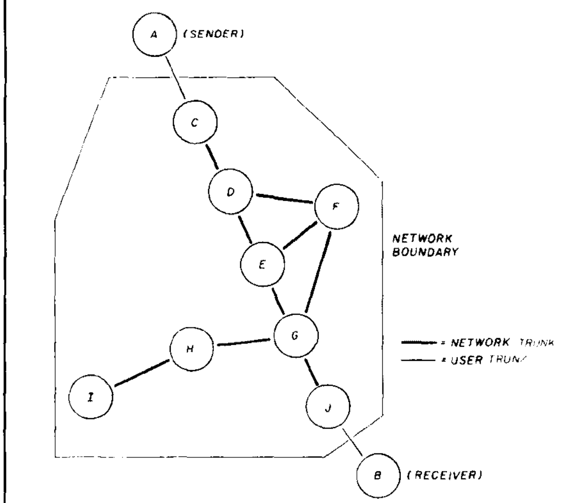


fig. 9. A Backbone network topology. A few alternate routes exist through the network, but single-point failures are possible. This is a low-cost network.

the network). The TEXNET-IP protocol adds 5 bytes of overhead to the front of every packet inside the network, but is not suited for use as a user layer 3 protocol.

network topologies

How should all of these network modes be physically located? How should the communication paths between nodes be set up? The topology of a network is a map of the network—that is, where the nodes of the network are located, and which nodes are within rf range of other nodes. The topology defines which nodes can be connected to each other, and gives a name to the different types of network configurations that could be made.

There are many topologies available for setting up a network, but we'll look at two common ones here. One way to set up a network—a "mesh" network—is shown in **fig. 8**. Mesh networks have many nodes, and many possible ways to route information between two users. Meshes also have a lot of "resilliency." They can suffer outages of nodes and/or paths, yet still have a way to route information between any two points.

Because the Texas Packet Radio Society doesn't have enough money to build and install switching nodes everywhere, we've chosen a topology that minimizes cost, but unfortunately degrades the survivability of the network. In our network, we've installed a "backbone" arrangement as shown in **fig. 9**. In this topology, nodes are installed along a "skinny" route between the major population centers — those users with the largest amount of traffic to send a long distance. Alternate routes to some of the paths are included. Each of the nodes contains a "table" in memory which is a map of the system, so that it knows to which node packets should be forwarded, depending upon which node will receive the packet and deliver it to the final user. These tables contain alternate routes in case the primary route is unavailable. In addition, each node contains an area in the memory where the routing table can be "patched" to accommodate recent changes to the map. These recent changes can be loaded into the network nodes by the network control operator. This type of routing is known as *static* or *directory* routing.

Further articles in this series will focus on specific issues addressed in implementing the TEXNET network. One section will be devoted to the hardware that was designed, and one section will be devoted to the software that was designed (protocol layers). The software section will also describe additional features provided by the network.

ham radio

simple ICOM IC-735 to C-64 interface

Software routine controls frequency, mode, memory channel, and VFO selection

This simple hardware and software interface can be used to control an IC-735 transceiver by means of a Commodore 64 using a serial data bus. With an understanding of the control codes listed in **table 1**, a routine can be written to perform many complex, useful operations with the IC-735 and, ultimately, to automate an entire station. Because future ICOM equipment will have the same data protocol, the program shown in **fig. 1** should be easily adaptable to those as well.

Figure 2 is a schematic diagram of the hardware used to interface the IC-735 to the C-64. Notice that the only component needed is a 4.8 k pull-up resistor. A more sophisticated design involving transistors and inverters for buffering is possible but not necessary because the C-64 user port is TTL-level compatible with the IC-735. The pull-up resistor is used to provide sufficient current to drive the input and output pins of Commodore's user port. Since this is a bidirectional data bus, both input and output pins in the C-64 user port are connected together. The flag interrupt is also connected to the bus for data detection and timing. As can be seen from the schematic, pins B, C, and M on the user port are pulled up to +5 volts through the resistor by a connection at pin 2 in the user port. The center connector of the REMOTE output of the IC-735 is then connected via a two-conductor cable to these data pins. The outside connector of the IC-735 REMOTE is connected through the same cable to pin N (GND) on the user port, thus completing the hardware interface.

Table 1. Control code designations and descriptions.

Control Code	Description
3	Requests transceiver to return its current operating frequency.
4	Requests transceiver to return its current operating mode.
5	Selects operating frequency.
6	Selects operating mode.
7	Selects VFO A or B
8	Sets parameters of selected memory channel.
9	Stores current configuration into displayed memory channel.
A	Stores current configuration into last displayed VFO memory.
NOTE: Codes 0 through 2, below, are not used in this program.	
0	Code used by transceiver when returning frequency after main dial or mode switch has been activated.
1	Same as 0 except data is for mode.
2	Request to return valid operating range.

code description

A line-by-line description of the entire listing is not necessary because of the functional similarity of the functional control blocks. (See **fig. 3.**) The details presented in the first block are useful for understanding the balance of the program.

housekeeping

Lines 10 through **599** contain a brief introduction, a definition of variables used, and a subroutine map. **Line 600** begins the functional part of the program by initializing the system. It opens the user port on the C-64, sets the screen color, clears the screen, and provides the data for the function keys. **Lines 750** through **950** display the main menu and prompt the user for the desired function.

frequency selection

The block of code beginning at **line 1000** is the first

Charles F. Bahr, N7ICW, 5621 North 40th Street, Tacoma, Washington 98407

```
10 REM ********************************
20 REM * FILE NAME: CSMA/CD            *
30 REM * THIS ROUTINE CONTROLS AN      *
40 REM * ICOM 735 HF TRANSCEIVER       *
50 REM * EQUIPPED WITH THE CI-V DATA   *
60 REM * BUS AND CONTROLLED BY THE     *
70 REM * COMMODORE 64.                 *
80 REM * REFER TO THE C-64 PROGRAMMERS*
90 REM * REFERENCE GUIDE PAGES 348     *
98 REM * THROUGH 357 FOR ASSISTANCE.   *
99 REM ********************************
100 REM
110 REM    BY:  CHARLES F. BAHR
120 REM         N7ICW
122 REM         5621 NO. 40TH
124 REM         TACOMA, WN. 98407
140 REM
160 REM
170 REM ----- VARIABLE DEFINITION -----
180 REM  FA = BAD DATA = 250
190 REM  FB = GOOD DATA = 251
200 REM  FC = JAMMER CODE = 252
210 REM  FD = STOP BYTE   = 253
220 REM  FE = START BYTE  = 254
230 REM  SR = STATUS REGISTER
240 REM  R  = RECEIVER ADDRESS
260 REM  C  = CONTROLLER ADDRESS
265 REM  F  = INPUT FREQUENCY
280 REM
300 REM ----- SUBROUTINE MAP -----
310 REM
320 REM  600   INITIALIZE
330 REM  750   MAIN MENU
340 REM  1000  SET FREQUENCY
350 REM  2000  SET MODE
360 REM  3000  SET VFO
370 REM  4000  SET MEMORY
380 REM  5000  PROGRAM MEMORY
390 REM  6000  MEMORY TO VFO
410 REM  8000  SOFT KEY SETUP
420 REM  8500  CLEAR SCREEN
425 REM  8600  RESULTS OF CHANGE
435 REM  8700  GET DATA
445 REM  8900  CONVERT TO HEXADECIMAL
450 REM  9500  ERROR PROCESSING
460 REM  9900  EXIT ROUTINE
470 REM
599 R=0
600 REM  ----- INITIALIZE SYSTEM -----
601 OPEN 2,2,0,CHR$(8)+CHR$(17)
602 REM 1200 BAUD,PARITY DISABLED,XLINE
605 DIM  K(20),Y(20),X(20),E$(20),V$(2),E(20),D$(20),D(20)
615 POKE 53280,0:POKE 53281,0:REM SCREEN AND BORDER
630 PRINT CHR$(30)
631 IF R>0 THEN GOTO 640
640 GOSUB 8500:REM CLEAR SCREEN
650 REM
680 DATA 1,SET FREQUENCY,2,SET MODE
690 DATA 3,SET VFO A OR B,4,MEMORY CHANNEL
700 DATA 5,STORE MEMORY,6,MEMORY TO VFO
705 REM
750 REM ----- MAIN MENU -----
755 REM
760 GOSUB 8500:REM CLEAR SCREEN
765 PRINT CHR$(30)
770 PRINT TAB(11)"MAIN MENU"
775 PRINT
780 PRINT
785 PRINT TAB(3)"CODE"TAB(10)"FUNCTION"
790 PRINT
795 RESTORE
800 FOR X=1 TO 6
```

fig. 1. ICOM-735 hf transceiver program.

```
805 READ D,B$
810 PRINT TAB(3)D TAB(10)B$
815 PRINT
820 NEXT X
825 PRINT
830 PRINT TAB(4) "ENTER CODE"
840 REM
850 GOSUB 8000:REM SOFT KEYS
860 GET A$
865 IF A$="" GOTO 860
870 A=ASC(A$+CHR$(0))
875 A=A-48
880 IF A$=CHR$(133) THEN GOTO 860:REM BLANK SOFT KEY
885 IF A$=CHR$(134) THEN GOTO 640:REM MAIN MENU
887 IF A$=CHR$(135) THEN GOSUB 7000:SYSTEM STATUS
888 IF A$=CHR$(135) THEN GOTO 631:REM REDISPLAY MENU
890 IF A$=CHR$(136) THEN GOTO  9900:REM EXIT PROGRAM
900 IF A<1 OR A>6 THEN GOTO 631
910 ON A GOTO 1000,2000,3000,4000,5000,6000
920 GOSUB 8500:REM CLEAR SCREEN
922 PRINT
924 PRINT
926 PRINT
928 PRINT
930 PRINT "     INVALID CHARACTER, TRY AGAIN."
940 FOR X=1 TO 2500: NEXT X
950 GOTO 760
1000 REM
1010 REM *************************
1020 REM * SET FREQUENCY ROUTINE *
1030 REM $ CONTROL CODE 05       *
1040 REM *************************
1060 GOSUB 8500:REM CLEAR SCREEN
1061 CLOSE 2
1062 OPEN 2,2,0,CHR$(8)+CHR$(17)
1110 REM
1120 FOR X=1 TO 10
1130 PRINT
1140 NEXT X
1150 INPUT "   ENTER NEW FREQUENCY IN MHZ ";F
1170 IF F<=30 AND F>=.1 THEN GOTO 1290
1180 PRINT "   FREQUENCY SELECTED IS OUTSIDE "
1185 PRINT "   BOUNDS OF IC-735. TRY AGAIN."
1190 FOR X=1 TO 2500: NEXT X
1200 GOTO 1060
1290 GOSUB 8900:REM CONVERT TO HEX
1300 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
1310 PRINT#2,CHR$(5)+CHR$(W)+CHR$(V)+CHR$(U)+CHR$(T)+CHR$(253)
1320 GOSUB 8700:REM VERIFY DATA
1330 CLOSE 2
1340 GOTO 600
2000 REM *******************
2010 REM * SET MODE        *
2020 REM $ CONTROL CODE 06 *
2030 REM *******************
2040 REM
2050 CLOSE 2
2060 OPEN 2,2,0,CHR$(8)+CHR$(17)
2080 GOSUB 8500:REM CLEAR SCREEN
2090 FOR X=1 TO 10
2100 PRINT
2110 NEXT X
2115 M=4
2130 PRINT TAB(3)"LSB";
2140 PRINT TAB(9)"USB";
2150 PRINT TAB(15)"AM";
2160 PRINT TAB(21)"CW";
2170 PRINT TAB(27)"FM"
2172 PRINT
2175 INPUT "   ENTER MODE:  ";M$
2180 IF M$="LSB" THEN M=00
2190 IF M$="USB" THEN M=01
2200 IF M$="AM" THEN M=02
2210 IF M$="CW" THEN M=03
```

```
2220 IF M$="FM" THEN M=05
2230 IF M=4 GOTO 2080
2240 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(242);
2250 PRINT#2,CHR$(06)+CHR$(M)+CHR$(253)
2260 GOSUB 8700:REM VERIFY DATA
2270 CLOSE 2
2280 GOTO 600
3000 REM *******************
3010 REM * SET VFO         *
3020 REM * CONTROL CODE 07 *
3030 REM *******************
3040 REM
3050 CLOSE 2
3060 OPEN 2,2,0,CHR$(8)+CHR$(17)
3120 GOSUB 8500 :REM CLEAR SCREEN
3130 FOR X=1 TO 10
3140 PRINT
3150 NEXT X
3160 V=2
3170 INPUT "   ENTER VFO A OR B";V$
3180 IF V$="B" THEN LET V=1
3190 IF V$="A" THEN LET V=0
3200 IF V=2 THEN GOTO 3000
3210 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
3220 PRINT#2,CHR$(07)+CHR$(V)+CHR$(253)
3230 GOSUB 8700:REM VERIFY DATA
3240 CLOSE 2
3250 GOTO 600
4000 REM **************************
4010 REM * DISPLAY MEMORY CHANNEL *
4020 REM * CONTROL CODE 08        *
4030 REM **************************
4040 REM
4050 CLOSE 2
4060 OPEN 2,2,0,CHR$(8)+CHR$(17)
4080 GOSUB 8500 :REM CLEAR SCREEN
4090 FOR X=1 TO 10
4100 PRINT
4110 NEXT X
4130 INPUT "   DISPLAY WHICH CHANNEL ";F
4150 IF F<=12 AND F>=1 THEN GOTO 4265
4160 PRINT "   CHANNEL SELECTED IS NOT AVAILABLE"
4165 PRINT "   ON IC-735. TRY AGAIN. "
4170 FOR X=1 TO 2500: NEXT X
4180 GOTO 4080
4265 GOSUB 8900:REM HEX CONVERSION
4270 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
4280 PRINT#2,CHR$(08)+CHR$(T)+CHR$(253)
4290 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
4300 PRINT#2,CHR$(08)+CHR$(253)
4310 GOSUB 8700:REM VERIFY DATA
4320 CLOSE 2
4330 GOTO 600
5000 REM *******************
5010 REM * STORE TO MEMORY *
5020 REM * CONTROL CODE 09 *
5030 REM *******************
5040 REM
5050 CLOSE 2
5060 OPEN 2,2,0,CHR$(8)+CHR$(17)
5120 GOSUB 8500 :REM CLEAR SCREEN
5170 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
5180 PRINT#2,CHR$(09)+CHR$(253)
5185 FOR X=1 TO 10:PRINT:NEXT X
5190 GOSUB 8700:REM VERIFY DATA
5200 CLOSE 2
5210 GOTO 600
6000 REM **********************
6010 REM * FROM MEMORY TO VFO *
6020 REM * CONTROL CODE 10    *
6030 REM **********************
6040 REM
6050 CLOSE 2
6060 OPEN 2,2,0,CHR$(8)+CHR$(17)
```

```
6150 GOSUB 8500 :REM CLEAR SCREEN
6170 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
6175 PRINT#2,CHR$(10)+CHR$(253)
6180 FOR X=1 TO 10:PRINT:NEXT X
6190 GOSUB 8700:REM VERIFY DATA
6200 CLOSE 2
6210 GOTO 600
7000 REM ****************************
7010 REM * SYSTEM MONITOR           *
7020 REM * CONTROLL CODES 03 AND 04 *
7030 REM ****************************
7040 REM
7061 CLOSE 2
7062 OPEN 2,2,0,CHR$(8)+CHR$(17)
7115 GOSUB 8500:REM CLEAR SCREEN
7120 FOR X=1 TO 10
7130 PRINT
7140 NEXT X
7240 M=3
7250 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(241);
7260 PRINT#2,CHR$(3)+CHR$(253)
7262 GOSUB 8700:REM GET DATA
7265 GOSUB 8600:REM RESULTS
7275 CLOSE 2
7280 OPEN 2,2,0,CHR$(8)+CHR$(17)
7284 M=4
7286 PRINT#2,CHR$(254)+CHR$(254)+CHR$(4)+CHR$(1)+CHR$(4)+CHR$(253)
7287 GOSUB 8700:REM GET DATA
7290 GOSUB 8626:REM RESULTS
7305 CLOSE 2
7310 RETURN
8000 REM ----- SOFT KEYS -----
8010 REM
8020 PRINT CHR$(18)
8030 PRINT CHR$(154)
8040 PRINT CHR$(19)
8045 PRINT
8046 PRINT
8047 PRINT
8060 REM PRINT TAB(33)"SYSTEM ";
8070 REM PRINT TAB(73)"MONITOR"
8100 PRINT
8110 PRINT TAB(33)"       ";
8120 PRINT TAB(73)"       ";
8130 PRINT TAB(30)"F3-MENU"
8140 PRINT
8150 PRINT
8155 PRINT
8160 PRINT
8170 PRINT TAB(30)"F5-SYSTEM";
8180 PRINT TAB(70)"   STATUS "
8190 PRINT
8200 PRINT
8220 PRINT
8230 PRINT TAB(30)"F7-PROGRAM";
8240 PRINT TAB(71)"   EXIT  "
8250 PRINT CHR$(146):PRINT CHR$(30)
8260 RETURN
8270 REM
8500 REM ----- CLEAR SCREEN -----
8510 REM
8520 PRINT CHR$(19)
8530 PRINT CHR$(147)
8540 RETURN
8600 REM ----- RESULTS -----
8606 FOR X=1 TO 15
8608 IF K(X)=253 THEN GOTO 8610
8609 NEXT X
8610 PRINT "FREQUENCY:";
8614 FOR Y=X-1 TO 6 STEP -1
8616 F=K(Y)/16
8620 PRINT INT(F)TAB(0)(F-INT(F))*16;
8622 NEXT Y
8623 PRINT
8624 RETURN
8626 M$=""
8627 PRINT
```

```
8628 PRINT "MODE: ";
8630 IF K(5)=00 THEN M$="LOWER SIDE-BAND"
8632 IF K(5)=01 THEN M$="UPPER SIDE-BAND"
8634 IF K(5)=02 THEN M$="AM"
8636 IF K(5)=03 THEN M$="CW"
8638 IF K(5)=05 THEN M$="FM"
8640 IF M$="" THEN GOTO 9500:REM ERROR ROUTINE
8642 PRINT M$
8643 PRINT
8644 PRINT "PRESS RETURN TO CONTINUE"
8646 GET K$
8648 IF K$<>CHR$(13) THEN GOTO 8646
8650 CLOSE 2
8660 GOTO 600
8700 REM ----- VERIFY/GET DATA -----
8702 GET#2,D$
8704 IF D$="" GOTO 8702
8706 FOR D=1 TO 15
8710 GET#2,D$
8725 K(D)=ASC(D$+CHR$(0))
8727 LET E=K(D)
8730 SR=ST
8735 IF SR AND 247>0 GOTO 9500
8740 IF E=251 THEN PRINT "   CHANGE ACCEPTED":REM VALID DATA
8745 IF E=253 THEN LET D=15:REM POST AMBLE
8750 IF E=250 THEN GOTO 9500:REM INVALID DATA
8755 IF E=252 THEN GOTO 9500:REM DATA COLLISION
8760 NEXT D
8770 FOR X=1 TO 2500:NEXT X
8785 RETURN
8790 REM
8900 REM ----- HEX CONVERSION -----
8902 REM F IS BROUGHT IN
8904 F=F+.000001
8906 T=INT(F)
8908 IF T>=10 THEN GOTO 8938
8910 F=(F-T)*10
8912 U=(INT(F))*16
8914 F=(F-INT(F))*10
8916 U=U+INT(F)
8918 F=(F-INT(F))*10
8920 V=(INT(F))*16
8922 F=(F-INT(F))*10
8924 V=V+INT(F)
8925 F=(F-T)*10
8926 F=(F-INT(F))$10
8928 W=(INT(F))*16
8930 F=(F-INT(F))*10
8932 W=W+F
8934 RETURN
8938 T=(T-(INT(T/10))*10)+(16*INT(T/10))
8940 F=(F-INT(F))*10
8950 GOTO 8912
9500 REM ----- ERROR PROCESS -----
9505 PRINT "   STATUS ERROR "SR AND 255
9510 IF SR AND 2=2 THEN PRINT "   FRAMING ERROR"
9515 IF SR AND 4=4 THEN PRINT "   RECEIVER BUFFER OVERRUN"
9520 IF E=250 THEN PRINT"   RADIO DETECTED BAD DATA"
9525 IF E=252 THEN PRINT"   DATA COLLISION DETECTED."
9530 PRINT:PRINT
9535 PRINT "   PRESS F1 TO RESTART"
9540 PRINT "   PRESS F7 TO EXIT PROGRAM"
9545 GET A$
9550 IF A$="" THEN GOTO 9545
9555 IF A$<>CHR$(133) THEN GOTO 9910
9560 CLOSE 2
9565 GOTO 600
9900 REM ----- PROGRAM EXIT -----
9910 GOSUB 8500
9920 CLOSE 2
9930 END

READY.
```

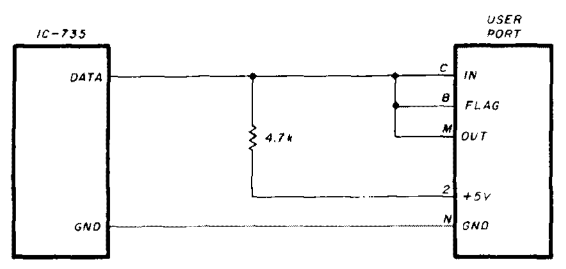


fig. 2. One pull-up resistor and several leads comprise total interface hardware requirements.

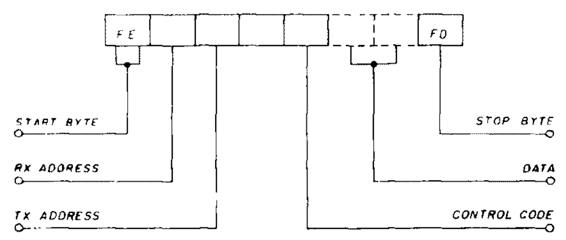


fig. 3. IC-735 data word format.

functional control block encountered by the program. It, like those that follow, begins by closing and reopening the user port and clearing the screen. **Lines 1150** through **1200** prompt the user for a new frequency. **Line 1290** calls a subroutine beginning at **line 8900** that converts the user input value to a hexadecimal format as required by the IC-735. On return from the subroutine, the hexadecimal representation of the new frequency is stored in variables T, U, V, and W, with T having the most significant digit and W the least. **Figure 4** gives the basic format of the data word. The IC-735 recognizes a hex "FD" (253) as the final character in the data stream and responds by returning its own data stream with either a valid data character or an invalid data character embedded. To verify the acceptance of the sent data, the program calls a subroutine at **line 8700** which isolates the check character and validates the data. This subroutine tests for data collisions between rigs, incorrect data transmissions, C-64 buffer overflow, and framing errors. If the data is acceptable, the program returns from the subroutine. Otherwise, it branches to **line 9500**, which identifies the error and gives the operator the option of continuing or ending the program.

mode control

Port control, data conversion and error checking are performed here and in the following functions in the same manner as in the frequency selection function. The block of code beginning at **line 2000** prompts the user for the desired operating mode and sets the transceiver accordingly. The acceptable modes are USB, LSB, a-m, fm, and CW.

VFO control

VFO control is performed by the block of code beginning at **line 3000**. The user is prompted to select the desired VFO, which is changed to a number, inserted into the character string, and printed to the Commodore's user port.

memory recall

Memory channel control is performed in the block beginning at **line 4000**. After the screen is cleared and the user port opened, the operator is prompted to select the desired memory channel. If the channel number selected is outside the bounds of the IC-735, the screen is cleared and the operator re-prompted for a correct channel number. The IC-735 is then programmed for memory mode and the character string to recall the selected channel sent after the channel number has been converted to its hexadecimal equivalent. It is important to remember that *any data sent to the serial bus must be in hexadecimal format.*

memory store

Storing the present transceiver frequency and mode into the displayed memory channel is performed in the code beginning at **line 5000**. This section requires no input from the operator because the current configuration of the rig is stored in the displayed memory channel automatically.

VFO programming

VFO programming is performed in the code beginning at **line 6000**. This section stores the transceiver's present mode and frequency into the last displayed VFO memory.

radio configuration

The transceiver's current frequency and mode is determined starting at **line 7000**. A character string with control codes 3 and **4** is sent to the rig. The transceiver responds by returning the current frequency and mode, which are decoded and printed to the monitor. Control is returned to the main menu after data has been verified.

subroutines

Housekeeping and support subroutines begin after **line 8000**. **Line 8000** begins a subroutine to provide visible "soft-keys" on the monitor screen. The legends on these "keys" correspond to the functions available on the Commodore "F" keys. **Line 8500** begins a "clear screen" subroutine. **Line 8600** starts a subrou-

tine that interprets data received from the transceiver in response to control codes 3 and 4. It calculates the frequency and mode from the data and prints the results. The subroutine at **line 8700** checks the incoming variable length data stream for validity and sets error flags accordingly. The subroutine at **line 8900** converts a decimal number to its hexadecimal equivalent. Error handling is performed by the subroutine at **line 9500**. Data failures for the IC-735 and Commodore are identified and the user is given the option of continuing or exiting the program.

summary

The hardware for this project is very simple: just an ordinary resistor. The software, though complex in appearance, is also quite simple. It provides the casual user the basic operational capability of an automated station. An experienced programmer can use the ideas presented here in more sophisticated applications or hang "bells and whistles" on the existing code. The possibilities are virtually unlimited. Automated control of Amateur equipment is the wave of the future. This little project is just one of the ripples.

ham radio

VHF/UHF WORLD

Joe Reisert W1JK

the ubiquitous diode: part 2

Last month's column discussed the electrical and mechanical properties of solid-state diodes, with emphasis on the most important parameters.[1]

This month we'll focus on specific applications using solid-state diodes, emphasizing circuitry and how to select the right diode for each particular application. Some of the applications we'll cover are rectifiers/detectors, regulators, mixers, switches, limiters, tuning elements, multipliers, oscillators, and optical devices.

simple diode applications

VHF/UHFers seldom give adequate notice to the use and abuse of low-frequency diodes. They forget that the diodes in a power supply or dc protection scheme are often just as important to system reliability and performance as the VHF/UHF diodes in rf circuits.

For instance, it makes little sense to use vacuum tube rectifiers, which generate rf noise and have a very short lifetime when compared with properly installed solid-state rectifiers. Furthermore, solid-state diodes are instantly ready to operate; no warm-up time is required. This is particularly important in bias supplies for high-power vacuum tube amplifiers where you need to have proper bias applied before energizing the high voltage.

While on the subject of high-voltage rectifiers, the economy and reliability of a single packaged unit is recommended.* Using strings of diodes, resistors, and capacitors for high-voltage rectifiers is an open invitation to failure and is really no longer cost-effective. I can attest to this because I once used such arrangements before complete packaged units were available.

Before leaving dc applications, don't forget the lowly "idiot diode." *If you leave it out you are an idiot.*[2] Idiot diodes are used to prevent connecting the dc power with reverse polarity to a solid-state circuit. Few solid-state devices will survive such an accident.

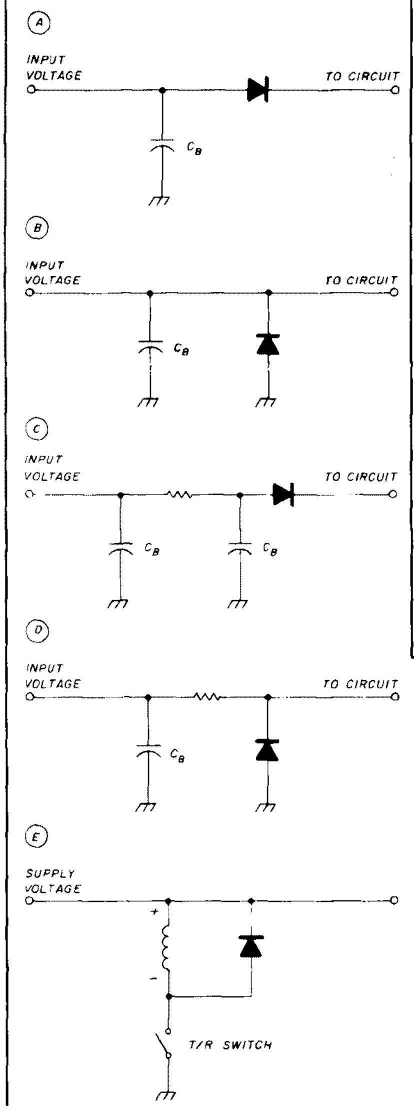
Some typical reverse protection circuits are shown in **fig. 1**. The circuit in **fig. 1A** is by far the most common,[2] but will induce an additional voltage drop of approximately 0.7 volts, which may be unacceptable, especially in power amplifier applications.[3] The circuit illustrated in **fig. 1B** eliminates the voltage drop problem. However, using a small signal type diode in this circuit may still cause burnout if the circuit is improperly powered. *Forward current in this circuit is limited only by the supply and the diode resistance.* Therefore, its protection effectiveness decreases if the power supply current capability is higher than the diode can handle.

The circuits illustrated in **figs. 1C** and **1D** are recommended to prevent idiot diode burnout. They can be used with small signal diodes if the voltage drop across the series resistor is acceptable. This is often acceptable, especially when using low-voltage devices such as GaAsFETs.[4] Typically 50 to 100 ohms of series resistance is sufficient.

However, some diodes, especially high-speed types or those designed for use in computers, are fast enough to respond to hf signals. Any rf coupled into the power supply line, especially from a local hf transmitter, can be rectified by the idiot diode and increase the circuit voltage above that from the supply alone.[5,6] Therefore a large (0.01 to 0.1 μF typical) bypass capacitor at the power supply input terminals is recommended to bypass any rf before it reaches the idiot diode.

Low-frequency diodes are also used to bypass relay coils (**fig. 1E**). This diode, which Amateurs often leave out, is recommended because the transient induced by the de-energizing of a simple T/R relay can cause large voltage spikes to appear on power supply lines.

Therefore, *never connect solid-state circuits, especially those used for low-*



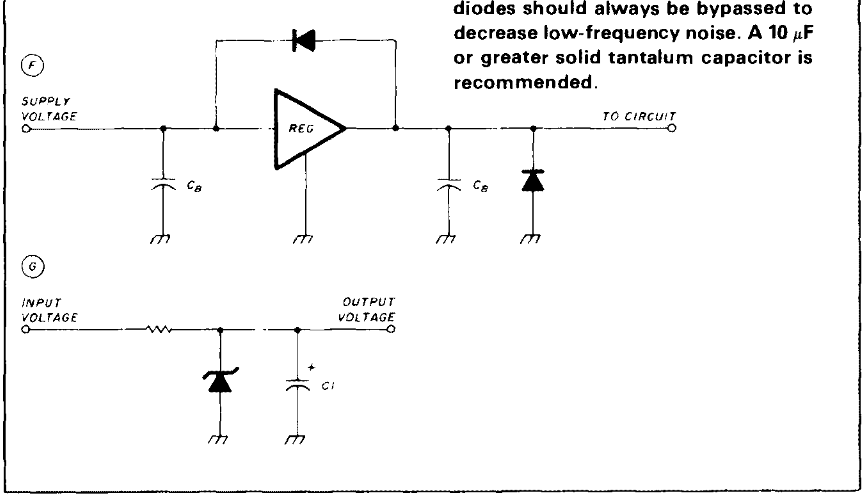


fig. 1. Typical solid-state reverse power supply protection circuits. In all circuits C_B is a 0.01 to 0.1 μF ceramic disc capacitor as recommended and described in the text. (See text for recommended protection diode types.) (A) is most common where the extra voltage drop is not important; (B) is used where no supply voltage drop is permitted. (C) is recommended for extra protection; (D) is used for extra shunt protection. (E) uses a reverse polarized diode across all relay coils to reduce inductive spike generation and (F) use a three-terminal regulator with two additional protection diodes to prevent regulator burnout. In (G) zener diodes should always be bypassed to decrease low-frequency noise. A 10 μF or greater solid tantalum capacitor is recommended.

noise amplifiers, to a power supply that is also used to supply a relay. This is an open invitation to disaster because the voltage spikes generated by opening a relay coil can destroy other circuits connected to the same power supply.[6]

The zener is another diode popular with VHF/UHFers. Actually, this type of diode is working in a normally forbidden mode — in the reverse biased or avalanche region. By careful manufacturing control, the breakdown voltage of the zener is predetermined along with the series resistance of the diode. The heat dissipation in the junction must also be removed so that thermal runaway or junction burnout does not occur.

A zener diode makes a reasonable voltage regulator or limiter with a stable breakdown voltage within a specified current range. Zeners should be used with care, however, especially as voltage regulators for oscillators, because they generate broadband low-frequency noise in the avalanche mode.

If you use a zener in an oscillator circuit, be sure to provide adequate low-frequency bypassing such as a high-value (10 to 100 μF) bypass capacitor (**fig. 1G**). Personally, I prefer to use the newer three-terminal voltage regulators rather than zeners because they are quieter and usually have a wider regulation range versus output current than most zeners.[4]

Finally, it has been shown that under certain operational conditions a three-terminal voltage regulator can be damaged. The addition of two extra diodes around the regulator is suggested (**fig. 1F**).[4]

rf detectors

One of the first major VHF-and-above applications of solid-state diodes was as rf detectors. This application, which dates back to the "good old a-m days," is still quite prevalent, especially as the detector in police radar! Rf detector diodes are also widely used today in VSWR and rf power meter applications.

Good rf detector diodes can be quite sensitive. The lowly point contact diode can detect rf below -60 dBm (200 microvolts rms in a 50-ohm system).[1] However, this will probably require some additional amplification at the output of the detector. At somewhat higher rf input levels (greater than -10 dBm or 70 millivolts), this same diode can directly drive a microammeter for power measurements.

Some typical rf detector circuits are shown in **fig. 2. Figure 2A** shows an optimized detector with an input matching network. Most detector diodes have a high input impedance. Therefore, the circuit in **fig. 2A** may exhibit narrow bandwidth.

If wide bandwidth is desired, the simple circuit in **fig. 2B** is usually used.[7]. It has lower sensitivity than a matched detector, but this is easily traded off for the wider bandwidth

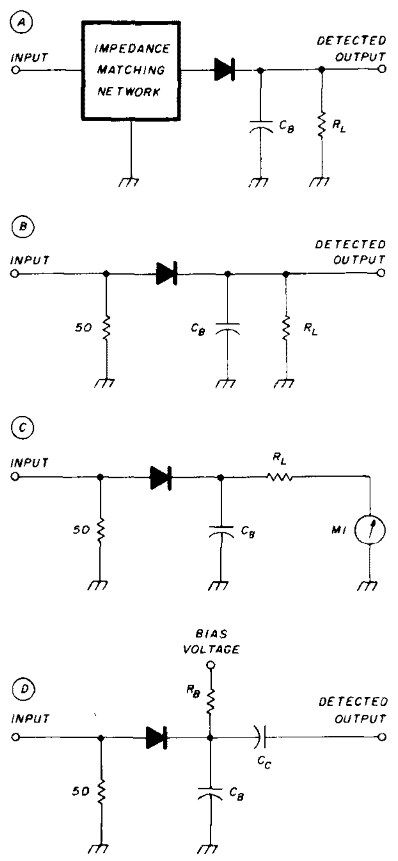


fig. 2. Typical diode detector circuits. (See text for recommended diode types.) In all cases C_B is an rf bypass capacitor. A feedthrough type 0.001 μF capacitor is recommended. R_L is the video load (10k ohms typical). (A) is recommended in narrowband applications where maximum detector sensitivity is desired. (B) shows a simple broadband detector. The 50-ohm resistor should have good rf characteristics. (C) illustrates a method for using the circuit shown in *fig. 2B* for power detection with a meter; (D) shows a method for increasing the sensitivity of an HCD by applying an external bias voltage. C_C is a dc blocking capacitor and R_B is the dc biasing current resistor as explained in the text.

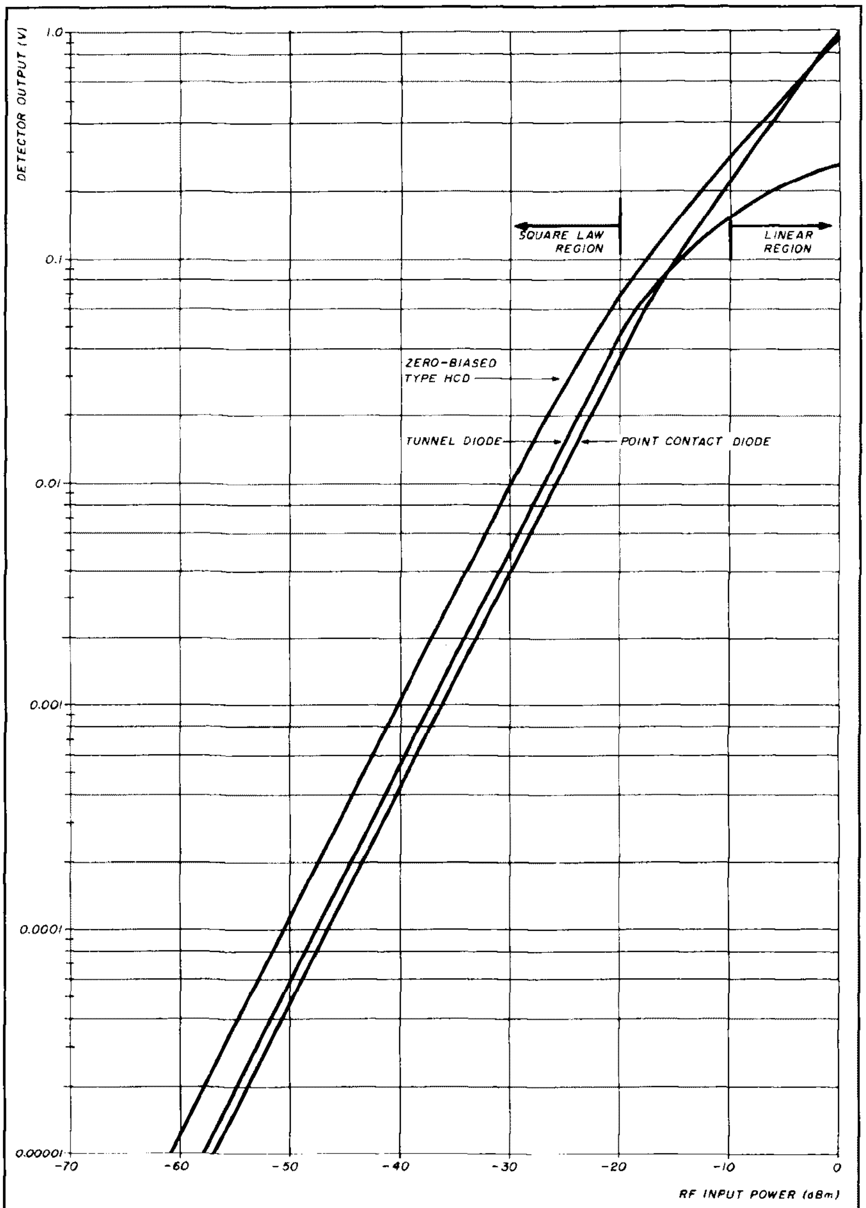


fig. 3. Typical output voltages for different types of detector diodes versus rf input power level into a 10-k load resistor using the circuit shown in *fig. 2A*.

capabilities. If a meter is added in series with the detector output load (**fig. 2C**), a detector can be used directly as a power meter over a wide frequency range.

Before designing a detector, it is important to compare the various types of diodes that were mentioned in reference 1. The most common detector types are the point contact, the silicon junction, and the Schottky or hot carrier diode (HCD).

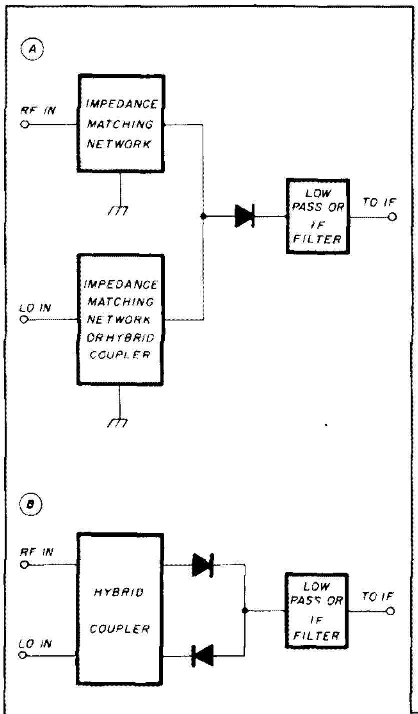
The point contact diode, the first sensitive solid-state detector diode, was followed by the much less sensitive junction diode in the late 1950s. First introduced in the 1960s, the HCD is 20 to 30 dB less sensitive than a typical point contact diode. However, the HCD is still more sensitive than the typical silicon junction diodes because it has a lower barrier voltage.[1]

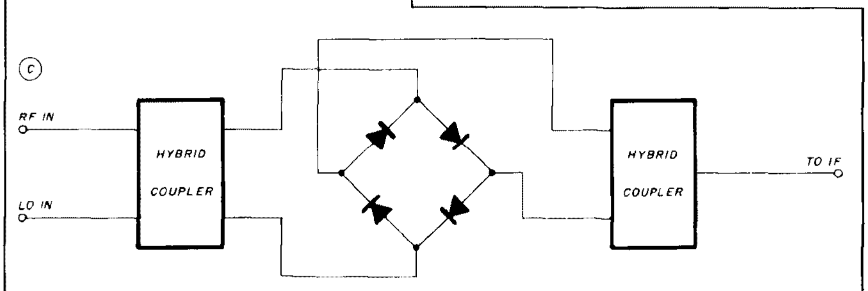
In the mid-1970s, the zero-bias HCD was developed. It has a very low barrier voltage, making it an ideal small signal detector. Typical input-versus-output voltages for the types of detector diodes just discussed are illustrated in **fig. 3**.

Note in **fig. 3** that below about -20 dBm (22 millivolts) most detector diodes have what is called a "square law" region where the output or detected voltage doubles each time the input power is doubled. However, above -10 dBm (70 millivolts) most detector diodes have a detected output voltage that is a linear function of the input power level. In between these rf levels is a very nonlinear region where compression takes place.

Nowadays, the low- to medium-barrier voltage HCD is usually preferred for detector applications. However, to make it competitive in dynamic range and sensitivity with point contact diodes, the barrier voltage must be overcome. This can be accomplished easily with a small amount (5 to 20 microamperes) of forward bias current applied as shown in **fig. 2D**.

Properly biased, the HCD offers greater forward conductivity (more output voltage for a given input power level), almost zero recovery time, and low cost. Furthermore, HCDs usually have a better impedance match than other types of diodes. They have vastly lower microphonics than other types of detector diodes. HCDs also have less flicker or 1/f noise, a phenomenon in which the noise figure of a device increases with decreasing frequency, especially below 10 kHz. Point contact diodes are very noisy and therefore unsuitable for radar applications, in which the information returned is in the very low or subaudible frequency range.





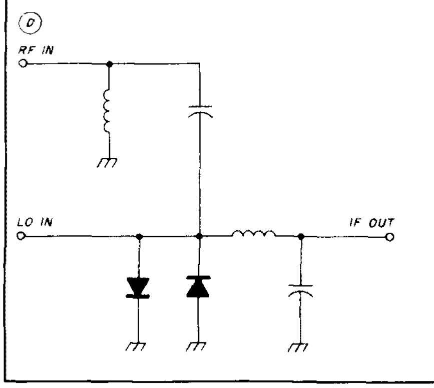


fig. 4. Some typical mixer circuits: (A) shows a single-ended mixer (see text for filtering explanation). (B) is a balanced mixer using a hybrid coupler to isolate the rf and LO. (C) shows a double-balanced mixer using two hybrids; (D) illustrates a subharmonic mixer using a pair of antiparallel connected mixer diodes.

Some precautions must be observed with HCDs. They normally have a low peak reverse breakdown voltage as discussed in reference 1. When a higher reverse breakdown voltage (15 to 75 volts) is required, a "guard ring" structure must be added internally to the diode chip by the manufacturer. However, this increases junction capacitance and thus decreases the upper frequency limits of operation.[1]

tunnel diodes

One diode that I didn't mention previously, but is often used for rf detectors, is the tunnel diode, sometimes referred to as the Esaki diode after its inventor, Dr. Leo Esaki, who discovered the effect in 1959. It's also referred to as a "back" diode because its main current flow is in the back biased rather than the forward biased direction. It has high sensitivity at very low rf input levels, utilizing the quantum mechanical tunneling effect.

Tunnel diodes may be manufactured using different semiconductor materials such as germanium, silicon, or gallium arsenide, depending on the frequency range desired. The main drawbacks of tunnel diodes are difficulty of manufacture (because they require a highly doped alloy junction), a lower burnout level, and a narrow dynamic range, typically only 40 dB, as opposed to 60 or more dB for a good point contact or zero bias hot carrier type diode (**fig. 3**).

mixers

Frequency conversion or mixing is the process which converts a signal at a low power level from one frequency to another by combining it with a higher level signal such as the local oscillator (LO) in a nonlinear device such as a mixer diode. In theory, this mixer diode generates an infinite number of sum and difference frequencies called the i-f or intermediate frequency as well as harmonics of the input and local oscillator frequency.

In practice, only a small portion of the available rf signal power is converted to the i-f. This ratio of signal level to i-f power is referred to as *conver-*

sion loss. This loss is primarily a function of the local oscillator level (or rf bias), the diode junction, the diode's parasitics, and the mismatch at the rf and i-f frequencies. At higher frequencies, the junction capacitance becomes a primary limitation because it tends to bypass the junction resistance.[1]

Figure 4A shows this mixing process schematically in a circuit which is usually referred to as a single-ended mixer. If the mixer is a downconverter, the typical receiver type, both the local oscillator and rf matching networks should be high-pass filters so that the i-f isn't shunted to the input. Conversely, the i-f port should be a low-pass filter type of matching network so that only the i-f is present at the output. For upconversion, the filters/matching networks are reversed accordingly.[9]

Most good detector diodes work well as mixers in a single-ended configuration. Point contact diodes were used for many years before the HCD was available. The HCD is preferred since it has lower parasitics, lower series resistance, higher conversion efficiency, and low storage time and the ability to switch from the on to the off state in almost zero time.

The single-ended mixer has many disadvantages. The matching networks all have loss and restrict bandwidth. As the i-f, rf, and LO frequencies converge, filtering becomes more complicated and the conversion loss increases accordingly. It is also difficult to adequately filter out all the frequencies causing increased conversion loss.

Some of the impedance matching disadvantages of the single-ended mixer can be overcome by using a 90- or 180-degree hybrid coupler in a balanced mixer such as shown in **fig. 4B**. The hybrid transformer isolates the LO and rf from each other. However, the i-f matching/filtering is still a problem and twice as much LO power is required. The double-balanced mixer or DBM solves most of these problems and is essentially two single-ended balanced mixers connected in parallel and 180 degrees out of phase (**fig. 4C**).

Actually, the DBM is really acting as a switch rather than a nonlinear junction. If the diodes are all similar (matched) and the transformers are well balanced, the rf, LO, and i-f ports will be well isolated from each other. Furthermore, there is suppression of the even-order harmonics, which significantly reduces intermodulation products. Finally, since the LO power is four times that required for a single-ended mixer, and less rf is across each diode, the intermodulation distortion is greatly improved.

Low series resistance and almost zero charge storage time make the HCD the ideal diode for a switching type of mixer. Furthermore, diode manufacturing technology now permits HCDs to be manufactured as either beam lead, monolithic pairs, or monolithic quads of diodes all closely matched on a single miniature sub-

strate with a minimum of parasitics.

The DBM works well as a mixer and is very simple to implement in up- or downconverters. Further use and applications of the DBM are discussed in references 8 through 10.

A newer type of mixer is the subharmonic configuration,[11] which uses two diodes in antiparallel connection (**fig. 4D**). The chief advantage of this type of mixer is that the LO operates at half the normal frequency, so fewer LO multipliers are needed; this represents a significant breakthrough on millimeter-wave frequencies.

switches

Diodes can make excellent switches because they usually require only low forward current and can be remotely situated from the power supply. Therefore they can be located close to the circuitry to be switched.

Because of its high speed and fast recovery time, the HCD can be a good switch. However, its series resistance may be too high if low insertion loss is important. The HCD is also a good rectifier, as discussed earlier. Therefore HCDs can introduce some loss and intermodulation distortion, especially if the rf level across the diode is sufficient.

The PIN (positive-intrinsic-negative), a three-layer diode, was invented accidently in 1956 and is now the most widely used solid-state switch. A PIN diode is actually no more than a lousy rectifier. The longer its "lifetime" (the inability to rectify in the presence of rf), the less likely it will be to cause intermodulation. Diodes with at least a 1- to 2-microsecond lifetime can be used in the hf region. Shorter lifetimes are fine at VHF and above.

When reverse biased, the middle or intrinsic layer of a PIN diode has extremely high resistance, with a small shunt capacitance. When a PIN diode is forward biased, it takes a finite time to switch to the "on" state. When forward biased, it acts like a current-controlled resistor: the greater the forward dc current, the lower the resistance.

PIN diodes are often used to switch rf because series resistances of less than 1.0 ohm are available. An example of a simple PIN diode switching circuit with low insertion loss is shown in **fig. 5A**. Low-capacitance PIN diodes will yield the highest isolation in the de-energized state, especially at the higher frequencies.

For very high isolation, two switch sections can be cascaded with a transmission line between the diodes (**fig. 5B**). For maximum isolation, the length of the interconnecting transmission line should be between 0.1 to 0.25 wavelengths, as explained in reference 5.

A typical two-pole PIN switch circuit is shown in **fig. 5C**. Commercially packaged two-pole, high-power switches suitable for switching over 100 watts through 1000 MHz (such as the M/A-Com MA8334 series) are now available. These high-power PIN diode pairs are available in a threaded stripline package for minimum VSWR

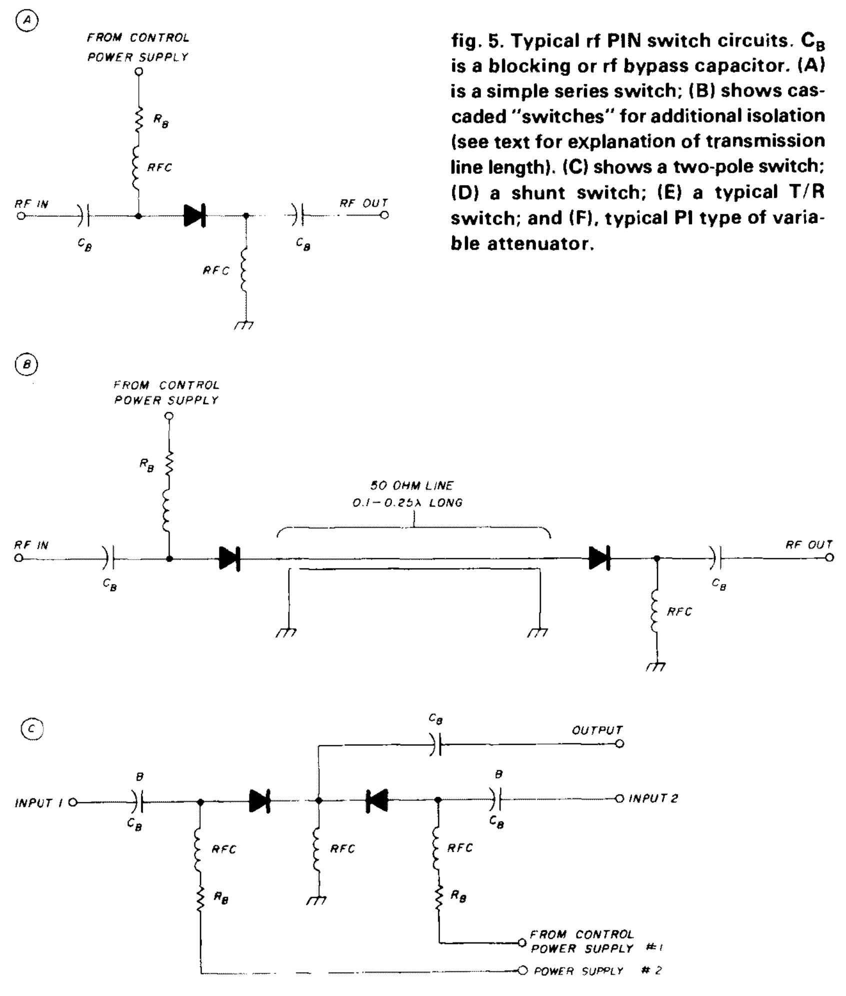


fig. 5. Typical rf PIN switch circuits. C_B is a blocking or rf bypass capacitor. (A) is a simple series switch; (B) shows cascaded "switches" for additional isolation (see text for explanation of transmission line length). (C) shows a two-pole switch; (D) a shunt switch; (E) a typical T/R switch; and (F), typical PI type of variable attenuator.

and maximum heat dissipation.

So far, the circuits illustrated use the series configuration. PIN diodes can also be used in shunt as illustrated in **fig. 5D**. An example of a shunt and series switch combination used as a T/R switch to provide extra receiver protection is shown in **fig. 5E**. Again, note the diode separation as described in reference 5.

Often used as variable attenuators, PIN diodes can have a very linear attenuation characteristic. The circuit shown in **fig. 5A** can be used as a variable attenuator by making R1 and/or the power supply voltage adjustable. More complicated circuits such as "L," "T," and "PI" types with up to three PIN diodes are also in wide use. An example of a typical "PI"-type variable attenuator circuit appears in **fig. 5F**.

Most PIN diodes specified for variable attenuator applications have a graded resistance versus control current, so you may need a wide range of current — 0.1 to 50 mA, typically, but this is a function of the type of PIN diode used. PIN diodes used for switching often require only a nominal fixed current. Remember that all PIN diodes used in the hf region must have longer charge carrier lifetimes to prevent intermodulation distortion.

tuning diodes

Varactors (sometimes called "varicaps" or tuning diodes) were first developed in 1958. Basically a voltage-dependent capacitor, as described in reference 1, it is always operated with reverse bias across the diode.

Most varactor diodes are used to vary the frequency of a filter or oscillator. Varactors are especially common in places where only a small capacitance change is required, such as in a BFO or RIT control. A typical remotely tuneable filter using a varactor diode is shown in **fig. 6A**; **fig. 6B** shows a VFO circuit application. High-*Q*, low-capacitance varactors are still used in parametric amplifiers, where the diode is pumped with an external oscillator (usually called the pump) to act as a low-noise, high-gain amplifier. Note that the electronic symbol for a varactor diode is different from a standard diode with a sort of capacitor symbol tacked on to the cathode terminal.

In some applications there is sufficient rf voltage across a varactor diode to cause forward biasing, rectification, and distortion — a very undesirable situation. This phenomenon can be significantly improved or eliminated by using back-to-back varactors as illustrated in **fig. 6C**. However, the capacitance of each diode must then be doubled because they are now in series.

Because so many types of varactor diodes are available, many different capacitance-versus-voltage, or "CV" characteristics, may be obtained. Some examples of CV curves were provided in **fig. 5** of reference 1, so they will not be repeated here. Examine the CV characteristics desired for your application to see whether abrupt or hyperabrupt tuning characteristics are required.

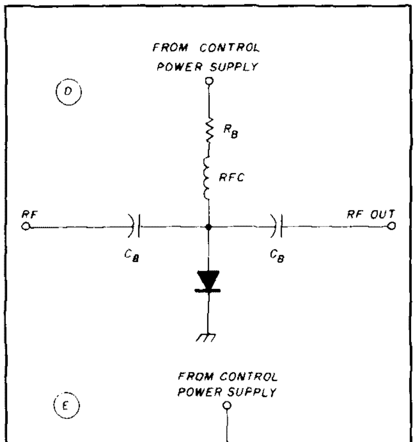
Finally, when selecting a varactor diode, always check the supplier's data sheet carefully for the recommended frequency range, *Q*, nominal capacitance at -4 volts (the standard reference voltage), and the available tuning range. Always operate a varactor so that it doesn't become forward biased. If that is a problem, use a diode with twice the capacitance and the circuit recommended in **fig. 6C** as just described.

multipliers

Diodes play a very important function as frequency multipliers. There are at least three types of diode multipliers in common use: varactor, resistive, and "step."

I'm sure that most readers have seen multiplier circuits where a diode is driven with a moderate amount of rf, typically 1 to 10 milliwatts, in order to generate harmonics. A typical circuit example is shown in **fig. 7A**.

In this particular application, the available harmonic power is primarily a function of the diode's nonlinear capacitance-versus-voltage characteristic and the stored charge in the diode, as mentioned earlier. In both regards, the point contact or typical silicon junction diodes (even 1N914s have worked!) are preferred because they generally have a greater nonlinear capacitance change near zero bias and are more likely to take longer to "dump" the stored charge, which is a desired characteristic of a good multiplier.



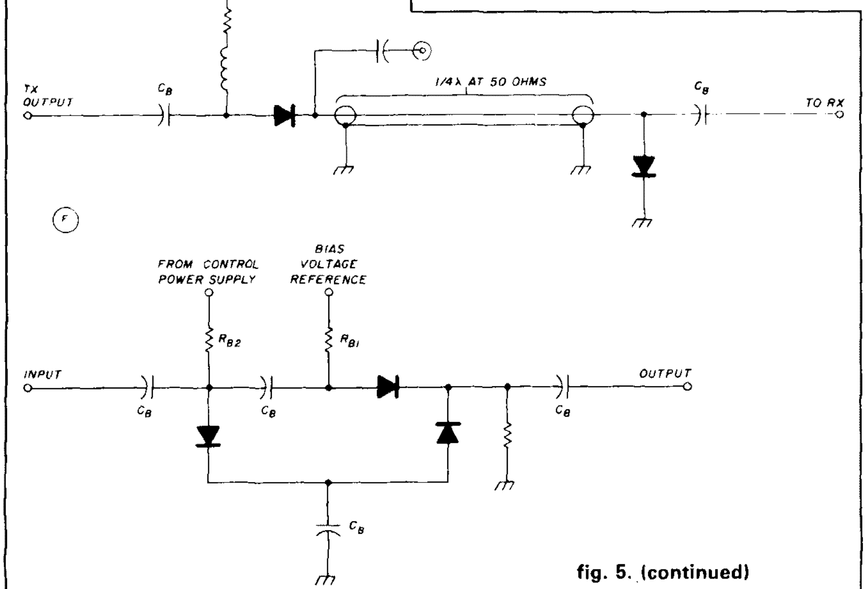


fig. 5. (continued)

The HCD would be a less efficient multiplier in the above configuration because it falls into the resistive multiplier class. It has very little capacitance-versus-voltage change (see **fig. 5** in reference 1) and is known for its quick switching response or ability to dump the stored charge almost instantly, as mentioned earlier.

However, if you operate an HCD in a balanced doubler configuration (analogous to a typical 60-Hz full wave power supply rectifier) similar to the frequency doubler circuit provided in reference 12, high efficiency can be obtained. Using HCDs in the circuit shown in **fig. 7B** yields good doubler efficiency results (only 6 to 12 dB conversion loss.) Furthermore, the fundamental and third harmonics are typically rejected by 20 to 30 dB. Hence less output filtering is required.

Although balanced HCD doublers have moderate conversion loss, they are very stable and have low noise. Sometimes they're easier to work with than transistor doublers. With the availability of silicon MMICs (microwave monolithic integrated circuits), the conversion loss of a balanced HCD or the single-ended diode multiplier as described above can be inexpensively brought back to unity or greater gain as described in reference 12. I've been using this technique for many years with great success, and was doing so even before MMICs were available.

Moderate power (5 to 50 watt) varactors have been used for many years as doublers and triplers up through 23 cm (1296 MHz). Diodes such as the surplus Microwave Associates MA 4060 low-cost, threaded-package, high-power varactor are in widespread use.[13] Even small signal varactors such as those discussed earlier for tuning oscillators and filters will work well at low input power levels (10 to 1000 milliwatts).

A typical varactor diode multiplier circuit (**fig. 7C**) consists of an input matching network, a varactor diode with its associated bias resistor, R_B and the output filter network. Although their efficiency decreases when varactors are used as triplers, it can be enhanced considerably by adding an idler circuit. This circuit consists of a high-*Q* series circuit tuned to the second harmonic of the input frequency (**fig. 7C**).

SRD multipliers

The SRD (step recovery or "snap" diode) is the "king" of multiplier diodes, especially when high efficiency and higher order multiplication (greater than 3 times) is required.[14] SRDs have a structure very similar to that of a PIN diode.

The capacitance of an SRD can usually be assumed to be independent of minor voltage changes and has a CV characteristic similar to that of an HCD[1]. When the *rf* input voltage goes positive, the diode turns on and stores a charge in the intrinsic region. When the applied voltage goes negative, it takes a finite time for the stored charge to decrease (the "snap" time), at which time the diode will abruptly turn off. During this transition period, the

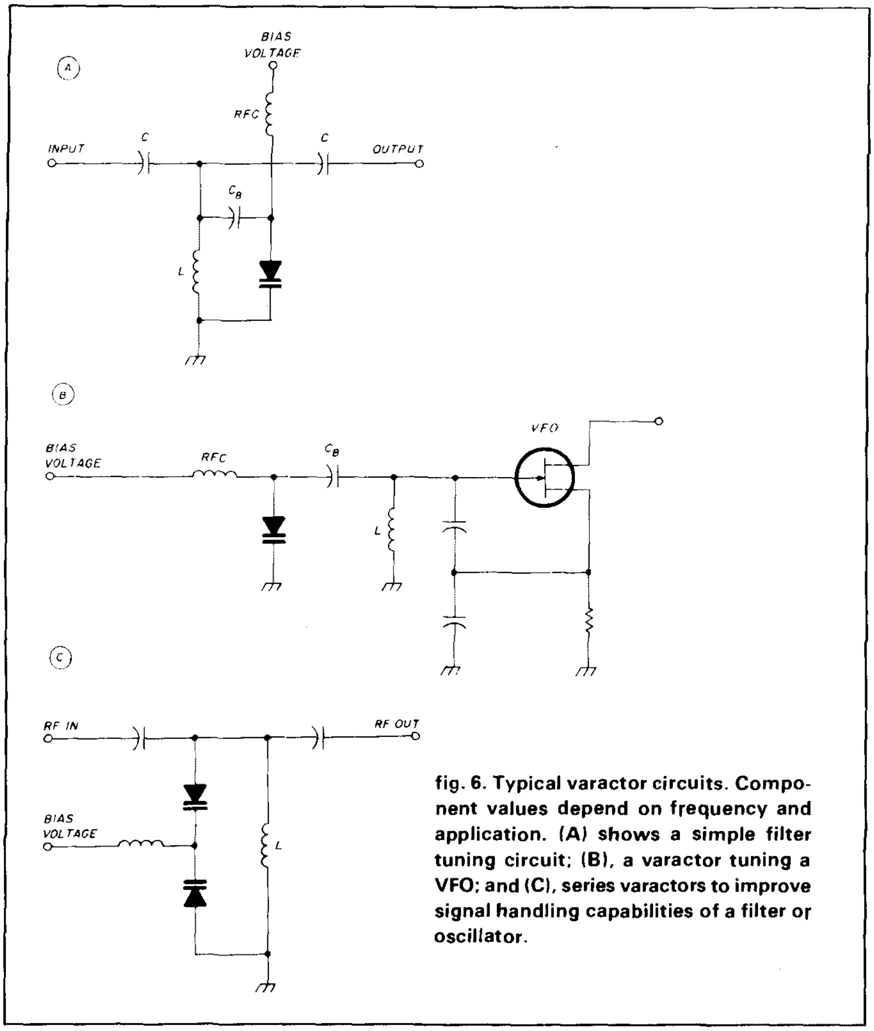


fig. 6. Typical varactor circuits. Component values depend on frequency and application. (A) shows a simple filter tuning circuit; (B), a varactor tuning a VFO; and (C), series varactors to improve signal handling capabilities of a filter or oscillator.

SRD conducts current for a very short period of time as if in a short circuit. This rf current is very rich in harmonics.

A typical SRD circuit is illustrated in **fig. 7D**. Note that the SRD has a different electronic symbol than other diodes. At first glance the circuit closely resembles that of the varactor multiplier (**fig. 7C**). However, there are a few subtleties. The input circuit has an extra section or "impulse" network, as illustrated. The bias circuit is slightly different. In the case of the SRD multiplier, a very low value bias resistor is used (typically 200 to 500 ohms, versus 50 to 100 kilohms for the varactor multiplier).

Another version of the SRD is the BIMODE™ or A mode™ diode, which is enhanced for high power and high efficiency operation as a doubler or tripler. For best efficiency as a tripler, this type of diode requires an idler circuit similar to the one in a varactor multiplier (**fig. 7C**).

SRD multipliers can have conversion losses as low as a few dB — hence their popularity as multipliers. SRDs are usually capable of operation at up to 5 to 10 watts of power. If higher power (up to 50 watts) is required, SRDs are available in stacked or multichip packages.

SRDs are often used as impulse or "comb" spectrum generators for generating harmonics over a large frequency spectrum, as described in reference 14. Further information on designing SRD multipliers or comb generators is beyond the scope of this month's column, but interested persons are encouraged to seek out copies of references 15 and 16.

limiters

It's often wise to place a circuit ahead of the input to your receiver to provide protection from stray rf, T/R relay leakage, or static.[6] Such a circuit is often referred to as a limiter. The simplest limiter is a diode, typically an HCD, connected to ground across the input line to a receiver (**fig. 8A**) or from the base to emitter of a bipolar transistor (**fig. 8B**).[2]

This type of circuit is poor at best because it conducts only on one side of the input signal. Back-to-back diodes (**fig. 8C**) are better. However, neither configuration provides any protection from stray out-of-band rf. As a result, if moderate rf power is present on your transmission line, harmonics that will overload or degrade receiver performance may be generated by the limiter. Furthermore, HCDs can handle only low power (less than 1.0 watt); because they have a very low barrier voltage, 0.3 volts, they are easy to overload.[1]

Placing a bandpass filter ahead of a limiter (**fig. 8D**) helps. (This was recommended in references 2 and 6.) A further limiter improvement would be to include the diode within the filter so that the capacitance of the diode could be tuned out. If the HCD barrier voltage is too low, diodes can be hooked in series until a suitable "turn-on" voltage is obtained. However, the HCD is a poor choice for a limiter diode because it's really a rectifier and doesn't have a very low impedance, even when turned on hard.

On the other hand, a PIN diode with a very thin I (intrinsic layer), typically 2-10 microns thick, makes an excellent rf limiter. PIN limiter diodes act like a power -dependent variable resistor with very low turn-on resistance through the mechanisms of charge injection and storage similar to rectification. Because of the long carrier lifetime of the PIN diode, only one di-

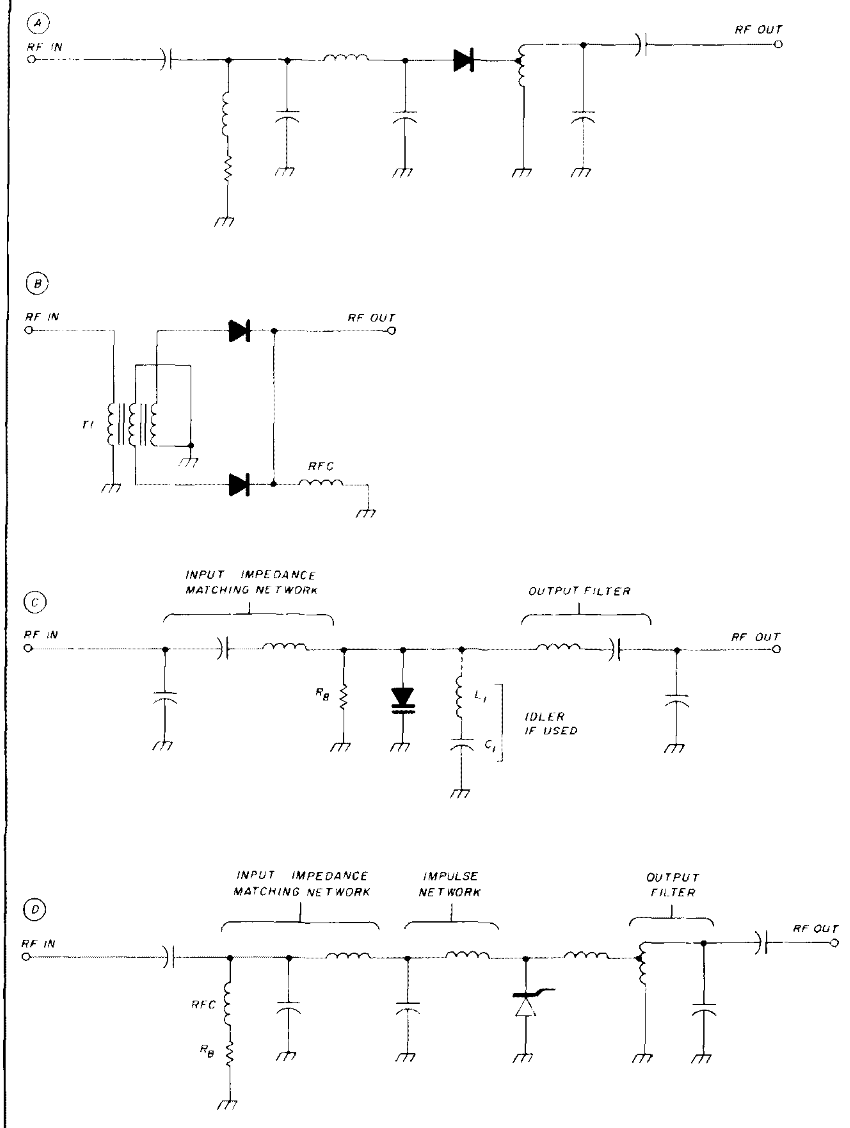


fig. 7. Typical multiplier circuits. Component values depend on frequency and application (see text). (A) is a simple diode multiplier. (B) shows a balanced doubler using HCDs, and (C), a varactor multiplier circuit. The idler circuit is used for tripler applications. R_B is typically 50 to 100 k. (D) is a typical SRD multiplier. R_B is typically 200 to 500 ohms.

ode is needed, since it stays on for a longer period than the rf cycle.

A single such PIN limiter diode can be substituted for an HCD (**fig. 8E**). If the I region is very thin, the diode can respond in nanoseconds. PIN limiter types of diodes have very low resistance and don't rectify the same as HCDs, as described earlier.

Thicker I region diodes with up to 50 nanosecond turn-on times are used for higher power operation. Power handling up to/in excess of 10 kilowatts for 1 microsecond duration is now possible! A thin and thick PIN limiter diode can be cascaded for additional protection (**fig. 8F**). Again, separate the diodes by 0.1 to 0.25 wavelengths, as discussed in reference 6. The inclusion of an HCD in the circuit shown in

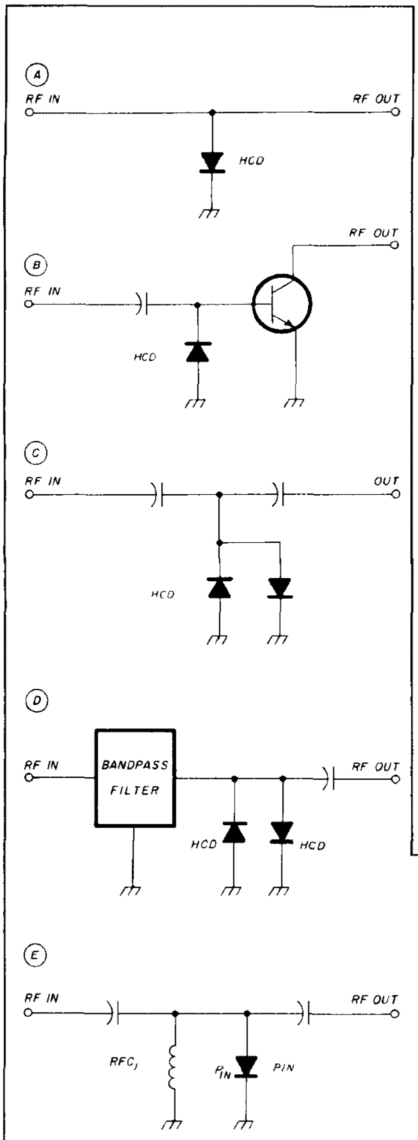
fig. 8G will help speed up turn-on time of a thick PIN limiter, especially at low power levels, for further low-power protection.

noise diodes

So far I haven't mentioned the noise diode, a special type that works in the avalanche mode similar to the operation of a zener diode. These diodes aren't always easy to construct and therefore are usually more expensive than conventional ones.

Noise diodes are particularly useful for testing receiver noise figures. Often Amateurs use point contact diodes (such as the old standby 1N21 type) in noise figure generators. Back biased transistor base to emitter junctions have also been used. Both of these diodes are tricky to use because they may have a low impedance and some reactive component when generating noise. Therefore, if you use them, place a large value (greater than 20 dB) attenuator pad between the diode noise generator and the device under test.

Good noise diodes generate "flat" or white noise over a wide frequency spectrum. Several microwave diode suppliers now supply noise diodes that are broadband and have excess noise ratios exceeding 35 dB. If you're interested in the subject, I'd suggest that you contact one of the suppliers, since this is a very specialized area.



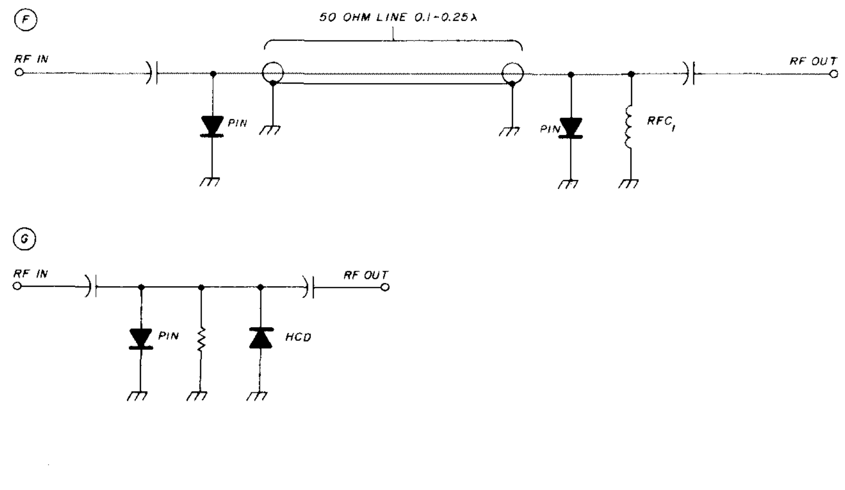


fig. 8. Typical limiter circuits: (A) shows a shunt diode; (B), bipolar transistor protection; and (C), a back-to-back limiter. (D) illustrates the preferred configuration for a limiter; (E) shows a typical single-ended PIN diode limiter; and (F) illustrates the use of two different PIN diode types for high power applications. (G) Adding a shunt HCD to a PIN diode limiter will improve turn-on speed and lower rf limit level.

oscillator diodes

These diodes were very popular before the arrival of efficient multipliers and bipolar/GaAsFET rf sources. Probably one of the earliest microwave diode oscillators used the negative resistance characteristic of a tunnel diode. However, tunnel diodes didn't generate much rf power.

Great excitement followed the invention, in 1963, of the Gunn diode, named for its inventor, Dr. J. B. Gunn, of IBM Research. A bulk-effect device that uses GaAs as the semiconductor material, it is terribly inefficient (typically less than 5 percent) but will generate up to several hundred milliwatts of microwave power in the 4- to 100-GHz spectrum if properly biased and designed into a suitable tuning structure. Gunn diodes are the main component in GunnPlexers.[9]

The many other types of microwave and millimeter-wave oscillator diodes include but are not limited to the TEO (transferred electron oscillator), TRAPATT (trapped plasma avalanche triggered transit), BARITT, IMPATT (IMPact-ionization Avalanche Transmit Time), and avalanche. The choice of an oscillator diode represents a tradeoff between frequency range, output power, power supply requirements, efficiency, and noise characteristics. No further discussion will be conducted at this time because there is probably only limited interest among Amateurs and stable sources followed by multipliers seem to be in current favor.

optical diodes

It would be unfair to ignore optical

short circuit

rewinding with CAD

Two corrections should be made to "Rewinding Transformers with CAD" by Hugh Wells, W6WTU (December, 1986, page 83). One line should be added and another changed as follows:

935 IP=VA/(0.9*EP):REM INTERIM CURRENT CALCULATION
940 CP=RC*IP^2:REM CALCULATES COPPER LOSS

---

diodes because they're really operational in the upper or top of the millimeter-wave region, beyond 300 GHz! Most operate in the visible light region. Probably the most inexpensive and well known is the LED or light emitting diode.

Another well-known type of optical diode is the LASER (Light Amplification by Stimulated Emission of Radiation). Amateur QSOs have been reported using lasers in the 474 THz region (474,000 GHz) region.[17] In this instance, a photodiode is used as the detector. I'd highly recommend reference 17 for those interested in communications by light waves.

Finally, let's not forget the common photovoltaic (solar) cells, which can be used to provide power for operating Amateur gear, especially in remote areas where commercial power is either unreliable or not readily available. Typical solar cells will generate approximately 0.5 volts per cell, so several may be connected in series to power typical Amateur equipment.

summary

In this and last month's columns, I've tried to show that diodes are still very important to the VHF/UHF/microwave and millimeter-wave enthusiast. Time and space didn't allow all diode types to be described nor full applications of all types to be noted.

Diodes are too often taken for granted because they're so small and have only "two terminals!" Just because diodes appear so simple is no reason to treat them lightly. I hope that the information and circuits provided here will answer some questions that I often hear asked about diodes and encourage greater appreciation for their proper use in Amateur applications.

new DX records

Last month's column announced a new 9-cm (3456 MHz) microwave DX record. Since that time more details have become available. WB5LUA, operating portable with 10 watts and a 4-foot dish at 2680 feet ASL in Mena, Arkansas (EM24UQ) contacted WA5TNY, who was operating portable at 600 feet ASL with 1.5 watts and a 6-foot dish in Fairy, Texas (EM11AU). Using CW, the two established a new North American DX record on this band of 288 miles (463.5 km) on October 19, 1986. Congratulations to Al and Rick as well as KD5RO, N5GEJ, N6CHA, and K5PS, who helped support this effort.

important VHF/UHF Events:

March 21	*± 2 weeks—Optimum time for TE propagation*
March 24	*EME perigee*
April 13	*ARRL 144-MHz Spring Sprint Contest (Monday evening)*
April 18	*EME perigee*
April 21	*ARRL 220-MHz Spring Sprint Contest (Tuesday evening)*
April 22	*Predicted peak of the Lyrids meteor shower at 1100 UTC*
April 24-26	*Dayton Hamvention*
April 29	*ARRL 432-MHz Spring Sprint Contest (Wednesday evening)*

references

1. Joe Reisert, W1JR, "The Ubiquitous Diode: Part 1," *ham radio,* February, 1987, page 51.
2. Joseph H. Reisert, Jr., W1JAA, "Ultra Low-Noise UHF Preamplifier," *ham radio,* March, 1975, page 8.
3. Joe Reisert, W1JR, "VHF/UHF World: Medium Power Amplifiers," *ham radio,* August, 1985, page 39.
4. Joe Reisert, W1JR, "VHF/UHF World: Low-Noise GaAsFET Technology," *ham radio,* December, 1984, page 99.
5. Joe Reisert, W1JR, "VHF/UHF Preamplifier Burnout," *ham radio,* November, 1978, page 43.
6. Joe Reisert, W1JR, "VHF/UHF World: Protecting Equipment," *ham radio,* June, 1985, page 83.
7. Joe Reisert, W1JAA, "VHF/UHF Techniques: Matching Techniques for VHF/UHF Antennas," *ham radio,* July, 1976, page 50.
8. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Receivers," *ham radio,* March, 1984, page 46.
9. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Exciters," *ham radio,* April, 1984, page 84.
10. Joe Reisert, W1JR, "VHF/UHF World: High Dynamic Range Receivers," *ham radio,* October, 1984, page 97.
11. M. Cohn, J. E. Degenford, and B.A. Newman, "Harmonic Mixing with an Antiparallel Diode Pair," *1974 MTT International Symposium,* June, 1974, pages 171-172.
12. Joe Reisert, W1JR, "VHF/UHF World: Broadband Amplifiers in Receiver Design," *ham radio,* November, 1986, page 91.
13. Joseph J. Moraski, K4USM, and Charles E. Spitz, W4API, "A Frequency Multiplier for 1296 MHz," *ham radio,* September, 1969, page 40.
14. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Frequency Calibrator Design," *ham radio,* October, 1984, page 55.
15. "Pulse and Waveform Generation With Step Recovery Diodes," *Application Note 918,* Hewlett Packard Company.
16. "Harmonic Generation Using Step Recovery Diodes and SRD Modules," *Application Note 920,* Hewlett Packard Company.
17. Steve J. Noll, WA6EJO, "Communicating on 474,083 GHz," *ham radio,* December, 1986, page 10.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

160-meter equipment: problems and design hints

The 160-meter band occupies a very special place in the history of Amateur radio.

On the night of November 27, 1923, a striking event occurred. Using a special wavelength near the "top band," 1MO and 1XAM of the United States made a transatlantic contact with French 8AB. American and European Amateurs were in QSO for the first time! A mighty ocean had been spanned and, at the same time, millions of dollars worth of commercial long-wave communication equipment had been rendered obsolete. Short waves were the coming thing, and the rush to explore the *very* short waves — possibly as short as 20 meters — was on.

Over the years, Amateur interest in the 160-meter band has waxed and waned. It's now on the increase, and there's a lot going on in this historic portion of the radio spectrum. Most modern transceivers cover the 160-meter band, and more Amateurs are turning to the "gentleman's band" as a source of enjoyment.

special problems of 160 meters

The 160-meter band is a lot closer to the a-m broadcast band than it is to any other Amateur band, and some Amateurs find that everyday techniques they're comfortable with, say, on 80 meters, don't seem to work as well on 160. This can bring about problems that are unique to this band.

Many Amateurs have transceivers that use the popular 6146B tubes in the output stage. Some of them have found, to their chagrin, that the transceiver won't load properly at 1.8 MHz, even though everything seems to work properly at 1.9 MHz or higher in the band. But at the low end, adjustments seem to "run off the end of the dial." In my case, my transceiver worked perfectly well down to about 1830 kHz, loading properly and providing a good 100-watts output into a 50-ohm dummy load. Alas, when I tuned up at 1800 kHz, the tuning control was fully counterclockwise, loading seemed sluggish, and the power output dropped to about 80 watts. Worst of all, the amplifier tubes ran very hot.

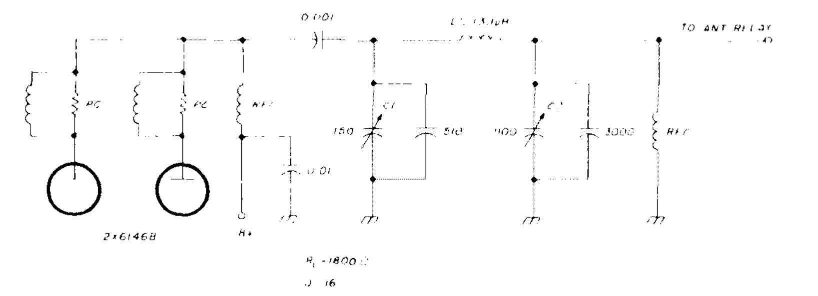


fig. 1. Representative output circuit of tube-type transceiver (160 meters). Pi-network is marginal at 1.8 MHz.

It didn't take much investigation to show that the amplifier plate circuit wouldn't tune that low in frequency — everything "fell apart" at about 1830 kHz. A phone call to the factory service center brought about the reluctant admission that operation was indeed "marginal" at the low-frequency end of the 160-meter band.

So — what to do? There was plenty of action around 1800 to 1810 kHz, and I thought it would be nice if the transceiver worked properly in this critical range — so near to the "outer limit" of the transceiver's design.

To determine the possibilities, the plate circuit of the transceiver (**fig. 1**) was examined with a computerized pi-network program, using the circuit values shown in the schematic in the transceiver manual. Sure enough, reaching the low-frequency end of the 160-meter band was outside the tuning limit of the transceiver — by the merest margin — about 30 kHz in my case.

I didn't like the idea of tearing into the transceiver to modify the circuitry, so I looked for another answer via the pi-network program. **Table 1** lists the component values needed for two different output impedances. Holding the plate impedance, circuit Q, and frequency constant, the output impedance was increased from 50 ohms to 75 ohms. The latter value was chosen because it's easy and inexpensive to obtain 75-ohm coax cable (RG-59/U and RG-11/U) and most transceivers are rated for a 75-ohm load. Note that while the value of the plate circuit inductance (L) remains fairly constant,

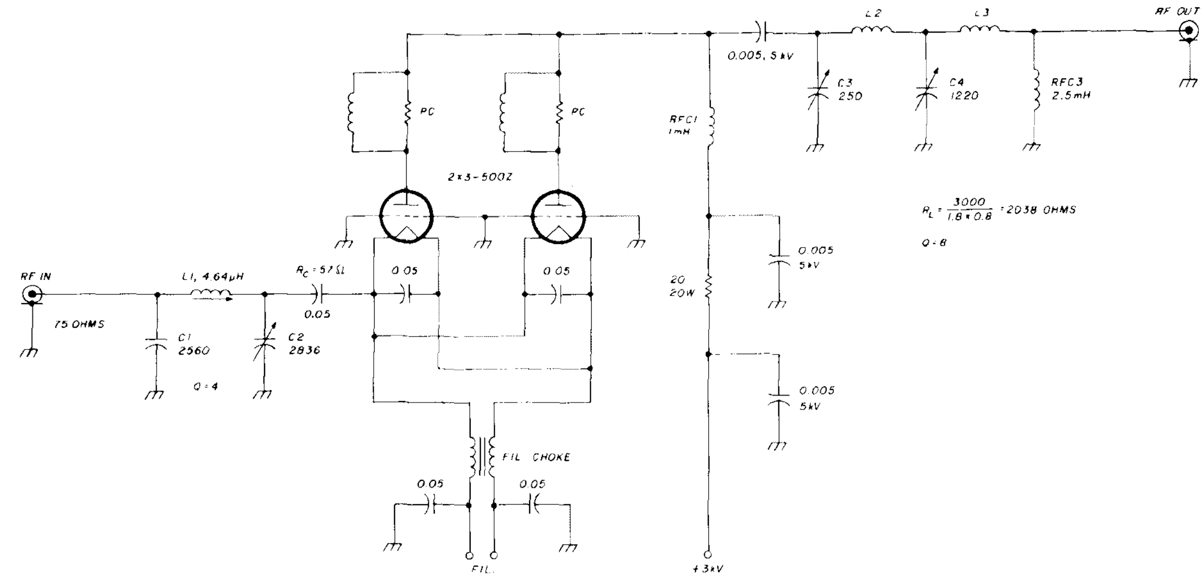


fig. 2. Representative 160 meter linear amplifier showing values of critical components. See text for data on RFC2.

both the tuning (C1) and loading (C2) capacitance values decrease by a noticeable amount. Switching to a 75-ohm feed system, therefore, can provide a greater tuning margin at 1.8 MHz for a given amplifier plate circuit network. Since the actual pi-network inductor wasn't changed, the tuning latitude gained isn't as much as predicted in this exercise, but it's still enough to permit an otherwise out-of-tune amplifier plate circuit to resonate properly at 1800 kHz. Accordingly, the transceiver was connected to a 75-ohm dummy load via RG-59/U coax and a 75-ohm model SWR meter. It was now possible to tune up properly at 1.8 MHz, with the amplifier tubes running much cooler.

Although switching to a 75-ohm feed system offered one solution, another equally satisfactory method consisted of adjusting the 50-ohm feed system to reflect the proper reactance back into the final amplifier that would detune the pi-network circuit in the proper phase to allow sufficient tuning range on the tuning and loading controls. This can be done by changing the coax line length between the antenna and the transmitter. Accordingly, various lengths of 50-ohm coax were inserted into the original antenna feed system until a length was found that permitted proper tuning of the transceiver. It's difficult to specify the "magic" length because that depends upon the antenna installation and the equipment in use. By changing coax cable length from antenna to transceiver, the tuning settings of the amplifier stage could be varied to produce a reasonable tuning sequence for the transceiver.

Table 1. Pi network component values for different load impedances.

Q	Frequency	C1(Input C)	L(Induct.)	C2(Output C)	Load Z
16	1.8 MHz	682 pF	13.11 µH	3708 pF	50 ohms
16	1.8 MHz	660 pF	14.00 µH	3020 pF	75 ohms

Note that changing the length of the coax did not change the SWR on the antenna system — it merely moved the transceiver back and forth along the coax line so that the combination of SWR and phase shift along the line produced the wanted results, namely, the ability of the transceiver to tune and load properly.

160-meter amplifier construction hints

Building a linear amplifier for 160 meters? No big problem, provided you remember that this creation is operating at a frequency closer to the broadcast band than to any other ham band, and design accordingly. The amplifier shown in **fig. 2** serves as an example. Only the rf circuitry is considered; the metering and control circuits aren't involved in this examination.

The first consideration is that all bypass capacitors have to be an order of magnitude larger than those values used on the higher frequency bands. For low-voltage, low-power circuits, a bypass or coupling capacitor of 0.05 µF is satisfactory. For high-voltage circuits, such as plate blocking and

bypass units, a value of 0.005 μF will suffice.

In low-voltage circuits, the Sprague "cera-mite" series of capacitors will do the job: the type 5HKP10 or 5GAP10 rated at 500 volts are satisfactory. For medium-high voltages, the Sprague 0.0047 μF, 6 kV (dc) capacitor, type 60GAD47 is suggested. Sangamo also makes a 500-volt dc-rated, 0.02 μF mica capacitor (FD203J03) that is satisfactory for low voltage circuits. Two of these units can be paralleled for 0.04 μF.

A larger-than-normal filament choke (RFC2) should be employed on 160 meters. If the choke is too small in inductance, it will tend to detune the pi-network input circuit because the choke is in parallel with capacitor C2 and introduces "negative capacitance" across C2, in addition to allowing rf power to pass down the choke and into the filament transformer. A suitable choke consists of 20 bifilar turns of No. 12 wire (Formvar) on a 0.5-inch diameter, 7-inch long ferrite rod (μ = 950).

A pi-L plate circuit is recommended to provide additional harmonic attenuation over that of a pi-network. Using high power, it's possible for the second harmonic of a 160-meter transmitter to fully meet FCC specifications, yet provide enough power in the 80-meter band to seriously affect nearby Amateurs operating close to the harmonic frequency. In this case, the pi-L configuration provides an extra 15 dB of second-harmonic attentuation at very little additional cost to the amplifier.

The greater rejection of this circuit allows the designer to decrease the network Q to provide smaller component values. In this case, a Q of 8 was chosen. The required component values for resonance at 1.8 MHz are given in the drawing. A total of 300 pF, with at least 100 pF of it variable, will serve as the tuning capacitor, and a total value of 2000 pF, with 1000 pF of it variable, will do the job as the output loading capacitor.

Transmitting-type, zero-coefficient ceramic capacitors (such as the Centralab type 850S) may be used to pad capacitor C3. Large, mica transmitting-type capacitors (often found at flea markets) can be used for padding the loading capacitor, C4.

The plate rf choke (RFC 1) must have sufficient inductance so that it doesn't affect the pi-L network to any great extent. From an rf point of view, the choke is in parallel with tuning capacitor C3. If the choke is too small, the value of C3 must be increased to compensate for the inductance of the choke. A minimum inductance for RFC 1 for 160-meter operation is about 250 μH. An inductance value up to 1 mH is more acceptable.

Note that the plate blocking capacitor has a value of 0.005 μF. This is considerably larger than found in amplifiers designed for the higher frequency bands.

A 20-ohm, 20-watt wire-wound resistor is connected in series with the B-plus lead. This serves as a low-Q rf choke for VHF harmonic suppression as well as a safety device in case of an ion flashover in the amplifier power tubes. The plate bypass capacitors on each side of this choke are 0.005 μF, 5 kV-ceramic units.

When such large coils as L2 and L3 are used in the plate circuit, it's imperative that they not couple to the cabinet. If an all-metal cabinet is used, it can easily become a one-turn, shorted inductor closely coupled to the output tank. This fact was brought to light in a homemade amplifier built within a steel enclosure. The efficiency of the amplifier was mysteriously low and the cabinet ran very warm — warmer than one would think, since an efficient cooling system was used. It was found that the circulating rf currents in the enclosure accounted for nearly 200 watts of output power! No wonder the cabinet ran uncomfortably warm! Rearranging the amplifier coils cured the power loss problem.

design summary

Coupling and bypass capacitors for a 160-meter amplifier have to be an order of magnitude larger than those chosen for an amplifier whose lowest

frequency of operation is 80 meters. In the same fashion, 160-meter rf chokes have to be at least twice the size (inductance) of their 80-meter counterparts. In particular, the B+ lead must be well filtered, or rf will skip down this lead, pass through the power supply and disappear down the primary power line, perhaps to light up a lamp bulb in a nearby receptacle! It's costly to generate rf watts on 160 meters and easy to lose them if care isn't taken in designing the equipment.

ham radio

C-64 and GLB PK-1 interface circuit

Get on packet quickly, easily with readily available components

Until just a few years ago, I thought that packet radio was an interesting part of our hobby, but one that was too difficult and too expensive to enter. I'd heard stories of people who spent months scrounging for parts and equipment.

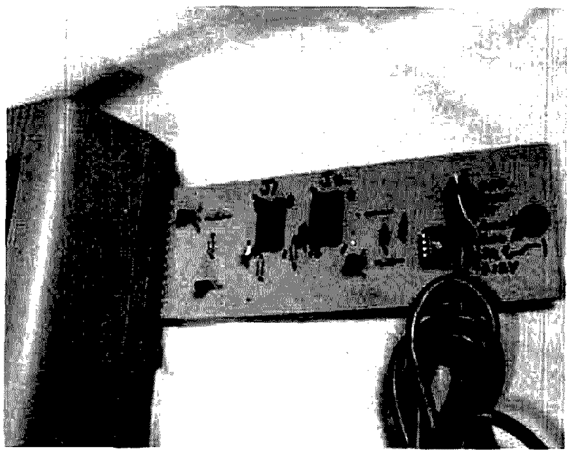


fig. 1. Interface card plugs into C-64 user port. On the author's version, the ribbon cables from J1 and J2 on the PK-1 are terminated in 16-pin DIP headers and plugged into IC sockets on the interface PC board. On later versions, the ribbon conductors were soldered to the PC board. The black dot at the end of the PC board is a rubber bumper which supports the free end of the board.

All that changed when GLB introduced the PK-1 Terminal Node Controller. For those of us who already owned a Commodore 64 computer, the PK-1 was about the cheapest way to go. Intrigued, Neil Abitabilo, WA2EZN, and I ordered two units from GLB.

We should have planned ahead. The PK-1s were only days from delivery when we realized that neither of us had the foggiest idea of how we were going to interface them with the C-64. One thing was clear; no one was offering an interface off the shelf.

Neil and I began making inquiries on the 145.135 repeater in Carmel, New York, where a large number of packeteers hang out. Eventually we got the information we needed to design a circuit that provides the necessary functions.

interface requirements

The DATA IN and DATA OUT lines between the PK-1 and the C-64 must be inverted. RTS and CTS lines from the PK-1 to the D and K pins on the user port must be linked without inverting polarity. A pc board serves as the common point for the three cables that link the various units.

Two ribbon cables connect J1 and J2 on the rear of the PK-1 to the solder pads on the pc board. A third cable (see **fig 1**) goes from the pc board to the transceiver for +12 volts, receive audio, transmit audio, push-to-talk, and squelch back-off (if used — see sidebar).

John B. Meagher, W2EHD/ex-W8JGN, 27 Fourth Street, Closter, New Jersey 07624

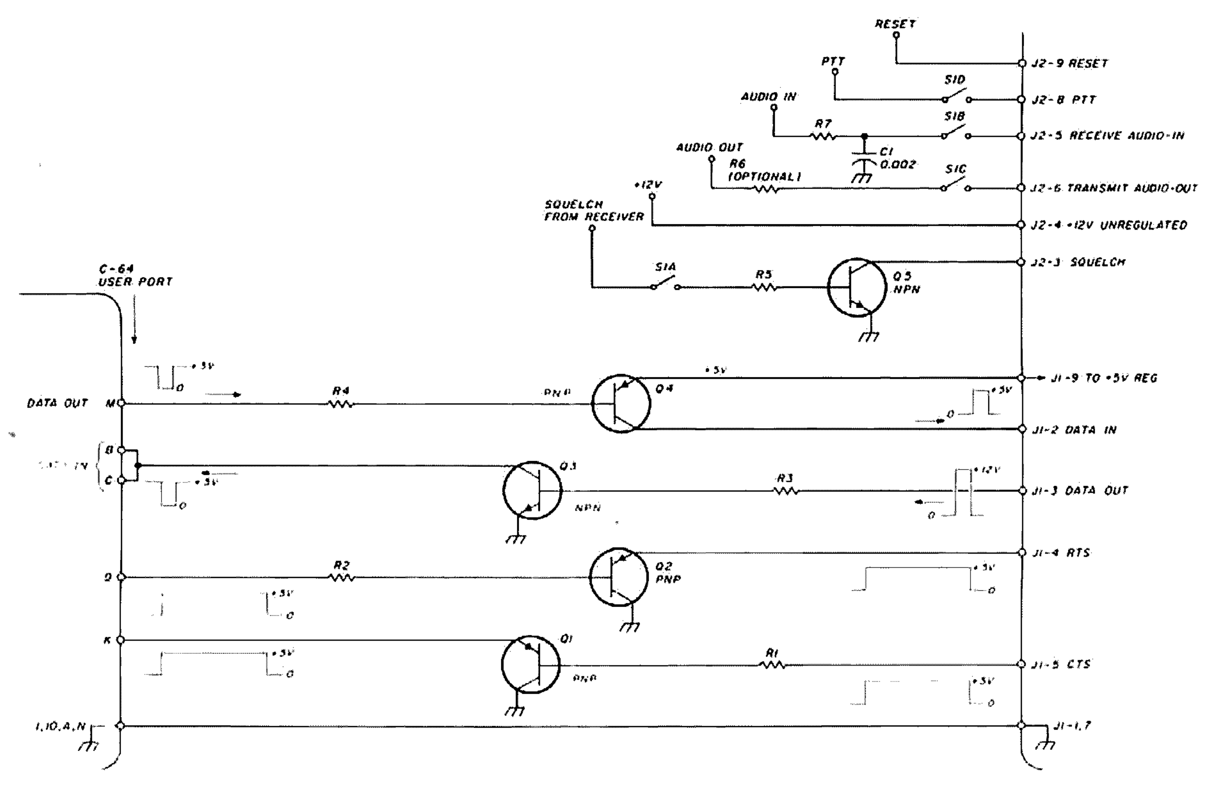


fig. 2. Interface card schematic.

C1	0.002 μF
P1,P2	5/10 0.156-inch insulation displacement edge connector (available from GLB)
P3	12/24 0.156-inch edge connector (Texas Instrument PN H411121-12). Available from Digi-Key PN C1-12
Q1,Q2,Q4	PNP (2N3906 or equivalent)
Q3,Q5	NPN (2N3904, 2N2222 or equivalent)
R1-R5	10 k 1/4-Watt, 10 percent
R6	18 k optional (see text)
R7	6.2 k optional (see text)
S1	4PST DIP switch

construction

Flexibility was a key consideration in board layout. S1 is a 4PST DIP switch which permits the operator to positively disable SQUELCH, BACK-OFF, PTT, RECEIVE-AUDIO and TRANSMIT-AUDIO. Neil and I found that there were times when we needed to isolate the PK-1 and the transceiver from the outside world for checks or experimentation.

Refer to the schematic (**fig. 2**) while reading the next few paragraphs. Note that R6 is optional. If the PK-1 packet audio to the transmitter can't be sufficiently reduced by R30 on the PK-1 board, then R6 can be inserted. The value can be determined experimentally. More than likely, however, it won't be needed, so it can simply be jumpered out.

R7 is also optional. We obtain receive audio for the

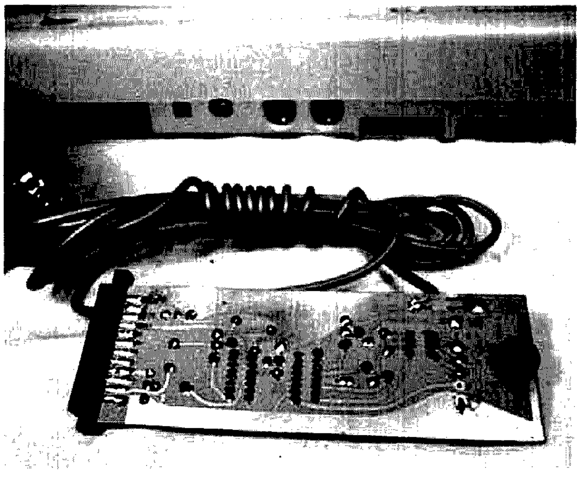


fig. 3. Bottom view of the interface PC board. The pins of the PC card edge connector are soldered to the contact fingers.

PK-1 directly from the discriminator. Initially, I was afraid that R29 (in the PK-1) might not provide adequate isolation to avoid overloading the discriminator. C1 is also an option. Some packeteers claim that oper-

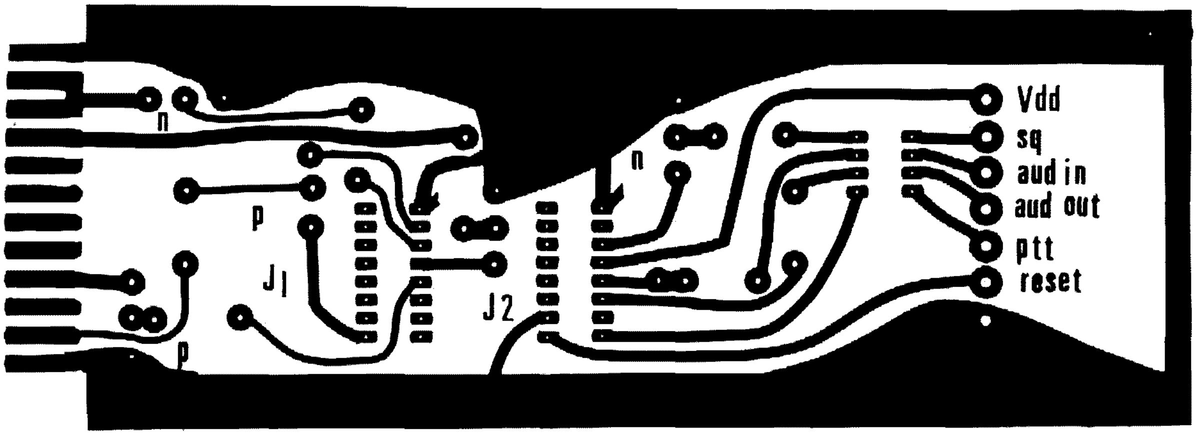


fig. 4. C-64/PK-1 interface card printed circuit diagram.

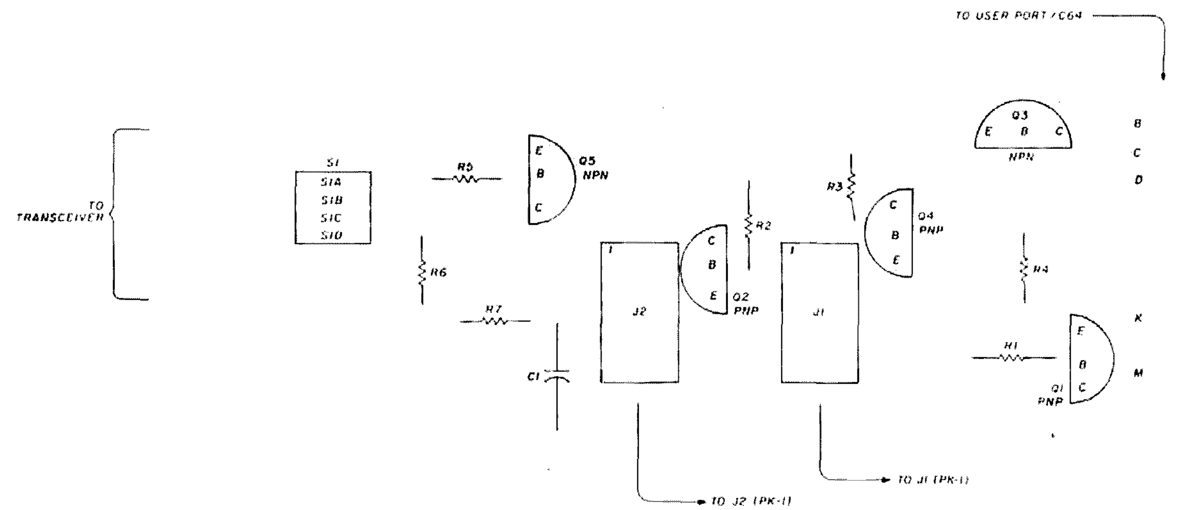


fig. 5. C-64/PK-1 interface card component placement diagram.

ation is more reliable if the high frequency components of the receive audio are rolled off. The values for base resistors R1-R4 are not critical. I used 10 k, but any value from 3.9 k to 15 k worked just as well.

At first we had a tough time finding a proper 12/24 pin, 0.156-inch pc edge connector to mate with the C-64 user port. The initial version of the interface board uses a connector that was cut to length with a hand-held jigsaw. Later, Terry McGraw, WA2UDG, discovered that TI makes one that's an exact fit (see parts list).

connections

The PK-1 requires 12 volts at 200 milliamperes. The simplest source is the transceiver with which the PK-1 will be used. After etching and drilling the pc board (**figs. 4** and **5**), connect the ribbon cable to the "IDC" (Insulation Displacement Connector) cable plugs for J1 and J2 on the rear of the PK-1. (Neil and I bought the connectors and the cable from GLB when we ordered the PK-1s.) Strip the other end of the ribbon cable conductors; before soldering them through the pc board holes, however, *make sure that the appropriate conductor from the plug goes to the correct pc board hole*. Double-check against the pin-out illustration in the GLB PK-1 owner's manual. (On the original version, the ribbon cables from the PK-1 terminate in DIP headers and plug into IC sockets on the board.)

The umbilical to the transceiver is next. You'll have to decide how to access the +12 volt bus, PTT, audio-

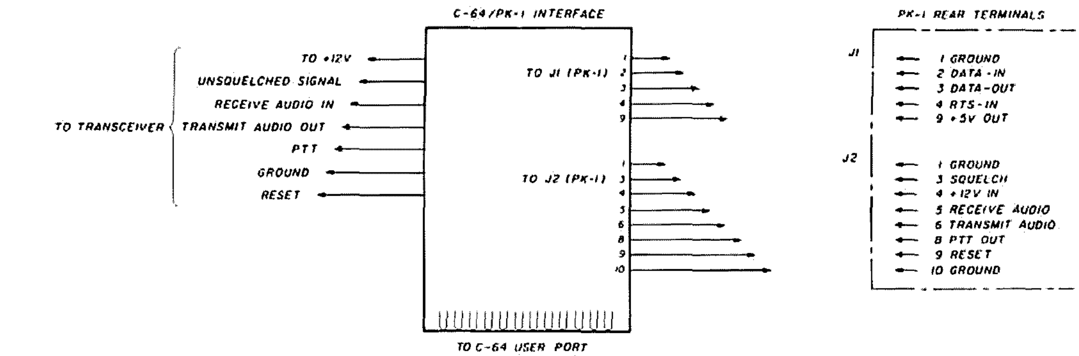


fig. 6. Interconnection diagram ties transceiver, interface and C-64 together.

in, and audio-out on your rig. Ben Spieker, WB2YSJ, kindly milled five fins from my Azden PCS-2000's heat sink and bored a 5/8-inch hole for a multipin connector. Note that there's a seventh conductor on the pc board labeled "Reset" (**fig. 6**). It's there if you want or need an external connection to the PK-1's reset line. Solder the lower (foil side) pins of the edge connector to each of the 12 "contact fingers" etched on the underside of the pc board. For mechanical strength, you could flow 5-minute epoxy or hot glue between the top pins and the component side of the pc board or use a couple of threaded spade lugs from the connector mounting holes to the pc board.

operation

Before applying power, check for any wiring errors. With power off, plug the interface cable into the transceiver. Turn on the transceiver, and with a voltmeter, check to see if +12 volts exists on pin 4 of J2. You should be able to key the rig by grounding the PTT line. A scope should indicate noise on the receive-audio line. (If you are picking off from the discriminator, 25 to 50 millivolts of noise will be present under no-signal conditions.) Turn power off and plug the cable connectors (J1 and J2) into the back of the PK-1. *Make absolutely sure the plugs go to the correct locations! Since they're identical and nonpolarized, it's a good idea to mark which is which to make sure they're not swapped or installed upside down!*

Make sure all four DIP switches on S1 are open, then turn on the power. The LED on the front of the PK-1 should light. (Note, so that you don't go crazy, when you input +12 volts via J2, the PK-1 front panel on-off switch is bypassed and has no effect.)

Remove power and plug the interface board (component side up) into the user port on the rear of the C-64. Turn on the computer, the transceiver, and the PK-1. Load whatever terminal program you wish to use for packet radio. (Neil and I have used a series of programs including *SuperTerm*, *Vidtex 4.0*, and the Texas Packet Radio Society's *TNC64*.

Once the program is running and you have packet traffic coming through the receiver, close the DIP switch that interrupts incoming audio. Packet traffic passing by should begin showing up on the computer monitor screen. Make sure the PK-1 is not in any of the following modes: OO (*display only connected packets*); OA (*display only stations with specified call signs*) or OQ (*store the packets in the PK-1 RAM*). If you're in any of these modes, no passing traffic will appear on the screen.

To test transmit, close the audio-out and PTT DIP switches and connect with a friend or with yourself through a local digipeater.

As good as it is, the PK-1 has no output timer to prevent a mishap from locking the transmitter on the air. WA3EZN and I have designed one we call the "Packetimer"; it's described in the following article.

monitor squelch status with "Back-off"

"Back-off" (Pin J2-3) permits the PK-1 to monitor the squelch status of the receiver. If the "back-off" pin is pulled LOW by a signal other than one from a packet station, the PK-1 is inhibited from transmitting. Without "back-off," the PK-1 and other TNCs ignore the presence of other non-packet signals and will transmit right over them. The interface has a transistor inverter (Q5) because the unsquelched signal from my transceiver (an Azden PCS-2000) is a HIGH.

Back-off is especially helpful where packet and fm phone operators attempt to coexist. It isn't as important if the channel is exclusively packet because TNCs are always inhibited from transmitting if they "hear" another packet signal.

"packetimer" for the PK-1

Handy circuit prevents lockup

In the previous article we described an interface circuit that allows the GLB PK-1 TNC to work with a Commodore 64. Soon after we put that combination into operation, one fact became obvious: the PK-1 has no fail-safe method of preventing accidental, long-term key-up. Amateurs not on packet may not realize the implications of this, but when it happens, your TNC "hears" the carrier of another packet station on the channel and automatically prevents the other transmitter from going on the air!

One evening, for reasons still unknown, my PK-1 locked up and sent 25 watts of rf through an 11-element beam for several hours. An unknown number of packet stations in the North Jersey/New York City area were suddenly struck dumb. No doubt their operators cussed out the dingbat whose carrier was blanketing 145.010. (If you were affected, my sincerest apologies!)

That's why we devised the Packetimer (see **fig. 1**), which is designed to go into action if the transmitter is on the air continuously for a length of time that exceeds the time-out period. Using the suggested component values, the device permits transmissions lasting up to about 30 seconds. Since 99 percent of the packet transmissions last well under 10 seconds, plenty of leeway is permitted, but a lockup (such as the one that occurred at this station) is no longer a threat.

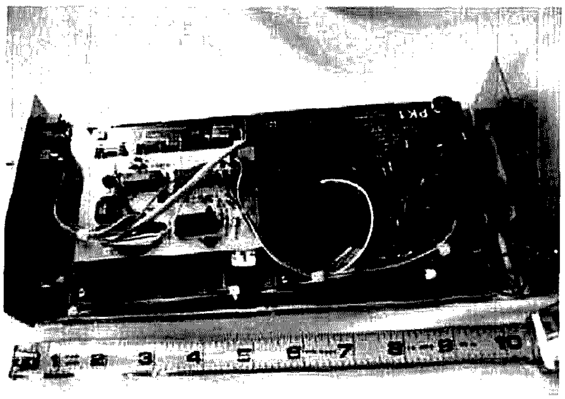


fig. 1. Side view of PK-1 with Packetimer installed. The wires from the PC board plug go to S1, CR6, +5v and the base and collector of PK-1 keying transistor, Q3.

operation

The Packetimer monitors the push-to-talk line from the PK-1 to the transmitter. Whenever the PK-1's keying transistor, Q3, pulls the PTT line LOW, U1 (the 4060 oscillator/14-stage binary counter) is activated through CR1 (see **fig. 2**).

The suggested values for C1, R2, and R3 yield a clock frequency of approximately 15 Hz. Within U1, the clock pulses are sent through a series of 14 flip-flops. Each flip-flop divides the incoming pulse train by a factor of two. In normal operation, the counters in U1 remain at zero because RESET (pin 12) is held HIGH through pullup resistor R1. *Only when the PTT line goes LOW (transmit mode)* can the flip-flops operate. The counters in U1 are reset to zero at the end of every transmission when the PTT line goes HIGH again.

However, in the event of a lockup condition, the counters keep going until the *Q* output to which CR2 is connected goes HIGH. When that happens, latch U3 is SET and its *Q* output (pin 2) goes HIGH. The HIGH from pin 2 of U3 does two things: it turns on Q1, which puts a stranglehold on the base of the PK-1's keying transistor, Q3. That takes the transmitter off the air and keeps it off. U3's output also turns on CR6, the blinking LED, and U4 (555) so that a continuous tone warns the station operator of the lockup condition.

The Packetimer must be manually reset via S1 before the packet station can transmit again. With the recommended values for C1, R2, and R3, and with CR2 connected to pin 1 (Q12 output) of U1, the transmitter can remain on the air for about 30 seconds before the Packetimer goes into action. Coarse divider increments (doubling or halving the time) can be achieved by shifting the jumper wire from CR2 to the next higher or lower *Q* output on U1.

John B. Meagher, W2EHD/ex-W8JGN, 27 Fourth Street, Closter, New Jersey 07624

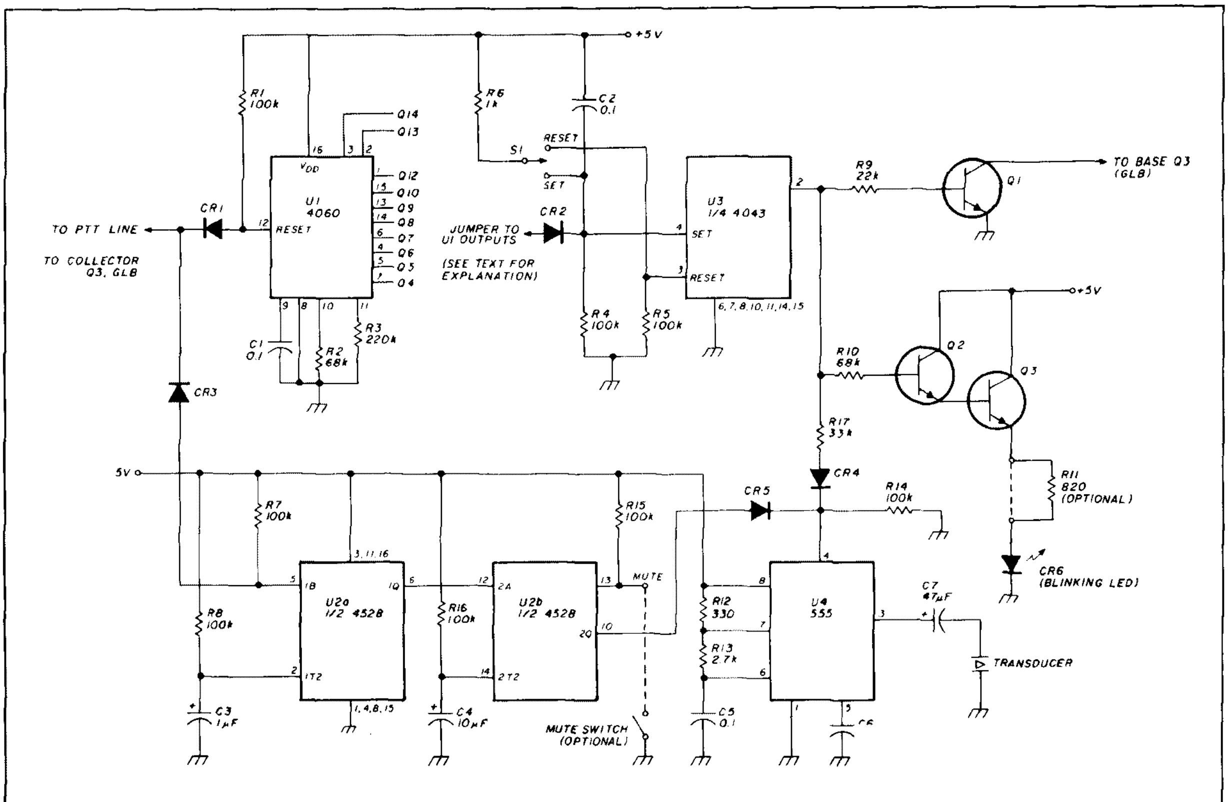


fig. 2. Packetimer schematic.

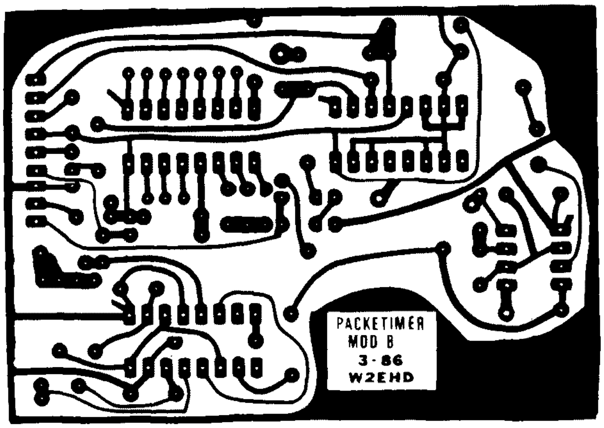


fig. 3. Packetimer full-size PC art.

The Packetimer beeps for about half a second whenever the PK-1 triggers the transmitter to send a packet. If the muted "tweet" from inside the PK-1 case gets on your nerves, simply ground pin 13 on U2 to shut it off. Don't worry; even if you decide to mute the beep, if the Packetimer is triggered, the continuous alarm will sound.

The purpose of C2 (between the +5-volt bus and the SET pin on the U3 latch) is to ensure that the Packetimer is latched ON (timed-out mode) at power-up.

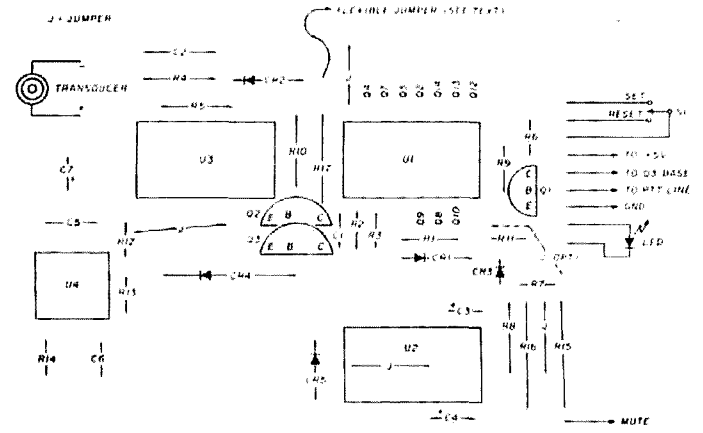


fig. 4. Packetimer PC board component placement diagram.

C1, C2, C5	0.1 μF, disc ceramic
C3	1.0 μF tantalum
C4	10.0 μF tantalum
C6	0.01 μF disc ceramic
C7	47.0 μF tantalum
	(All capacitors 12 VDC or better)
CR1-5	Silicon (1N914 or equivalent)
CR6	Blinking LED RS No. 276-036; Marlin P. Jones No. OP-2364
Q1,2,3	NPN Silicon (2N3904 or equivalent)
R1, R4, R5, R7, R8, R14, R15, R16	100 k
R2, R10	68 k
R3	220 k
R6	1 k
R9	22 k
R11 (see text)	820 ohms
R12	330 ohms
R13	2.7 k
R17	33 k
(All resistors 1/4-watt, 10 percent)	
S1	SPDT center-off toggle switch
U1	4060 (CMOS oscillator/14 stage divider)
U2	4528 or 4098 (CMOS dual one-shot multivibrator)
U3	4043 (CMOS quad set/reset latch)
U4	555 timer
Transducer	RS 273-069 or Marlin P. Jones No. SU-2205

This eliminates the possibility that a power glitch might wipe your terminal program from the computer and latch the transmitter on the air.

construction

The pc board (**figs. 3** and **4**) is straightforward. Note, however, that to avoid going to a double-foil board layout, three jumpers must be installed on the component side. Note, too, that R11 (820 ohms) is optional. If you use the Radio Shack blinking LED or the one from Marlin Jones, R11 is then replaced by a jumper. The devices contain their own current-limiting circuitry. If you install an ordinary LED, R11 must be installed to limit the LED current to a safe level. Both CR6 and S1 (the Packetimer manual set/reset switch) are added to the PK-1 front panel.

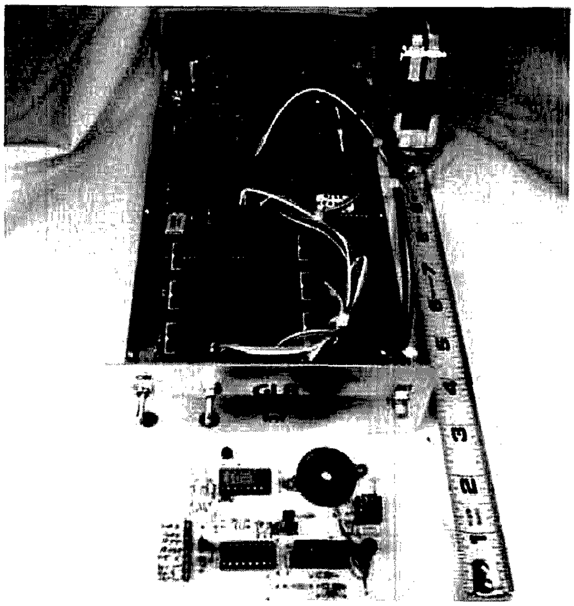


fig. 5. Front view of the PK-1 shows the added switch (S1) and LED (CR6). The packetimer is unplugged from the cable harness to show the Radio Shack transducer which is held to the PC board by a couple of dabs of hot glue. If the transducer from Marlin P. Jones is used, it can be soldered directly to the PC board.

connections

Two connections must be made to the PK-1 keying transistor, Q3. The first goes to the collector of Q3. This is where the Packetimer monitors the PTT line. The second connection is to the base of Q3 from the Packetimer's key-inhibit transistor (Q1). The ground connection on the Packetimer goes to the ground foil on the PK-1. The LM7805 voltage regula-

tor (Z6) in the PK-1 is a convenient source for the +5 volts needed by the Packetimer. With the GLB board edge terminals facing away from you, the +5-volt output terminal is the one on the right-hand side. If there's any uncertainty, it's easy to double-check with a voltmeter while the GLB is powered up. You'll find +12 volts on one side, zero volts (ground) on the middle terminal, and +5 volts on the other side.

installation

There are a number of options for mounting the Packetimer in the PK-1. A small piece of double-sided foam tape works well to attach the pc board to the top of one of the 6116 RAM chips. The circuit pads for external connections to the Packetimer are on 0.1-inch centers to facilitate a plug and harness installation (see **fig. 5**). If the Packetimer is removed, there's no effect on the operation of the PK-1 other than loss of the time-out protection.

testing

You can check the completed Packetimer on the bench. Connect ground and +5 volts. LED CR6 should start to blink and a steady tone should come from the transducer. If you short the pin that goes from the arm of the reset switch (S1) to the reset pin, the flashing and the noise should stop. With power still applied to the Packetimer board, ground the pin that will be connected to the push-to-talk line. It should give you a brief beep. Next, hold the PTT pin low with a grounded alligator clip and see how much time it takes for the alarm to go off. If the anode of CR2 is wired to pin 1 on U1 (4060), the Packetimer should sound the alarm in roughly 30 seconds.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

building the "poor man's spectrum analyzer"

In September 1986 an exciting article on spectrum analyzers appeared in *ham radio* ("Low-Cost Spectrum Analyzer With Kilobuck Features," page 82). Having been in both communications servicing and engineering school, I'd used spectrum analyzers, but never owned one. (Most professionals can't afford them.) I once considered purchasing a plug-in spectrum analyzer to fit our existing biomedical electronics laboratory oscilloscope mainframe, but it cost over $12,000! Then came W4UCH and his article on the very affordable WA2PZO/Science Workshop "Poor Man's Spectrum Analyzer."[1] I decided to build my own spectrum analyzer.

The WA2PZO concept is based on the fact that modern TV tuners, especially the "cable-ready" variety, are varactor-tuned. The familiar switched inductor tuner is replaced by a voltage-tuned varactor oscillator. Two types are available: one, which was used in the W4UCH article, has separate low-VHF, high-VHF, and UHF bands. A switch is used to select band coverage. The second is a wide-range "cable-ready" tuner that tunes from low VHF through UHF television bands in one 0-35 volt (some are 0-30 volt) range. Obviously, if you can modulate the tuning voltage with a sawtooth waveform (see "Practically Speaking," January, 1987, page 89), then you have a swept tuner. Demodulate its amplified i-f output and display it on a 'scope, and you have a spectrum analyzer. Sheer genius! I bought both forms of tuner from Science Workshop; **fig. 1** shows the cable-ready, wide-range model.*

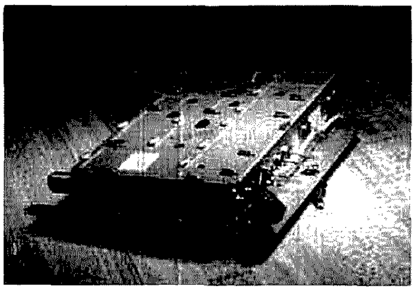


fig. 1. Wide range, L-VHF/H-VHF/UHF, voltage-tuned "cable ready" TV tuner used by the author.

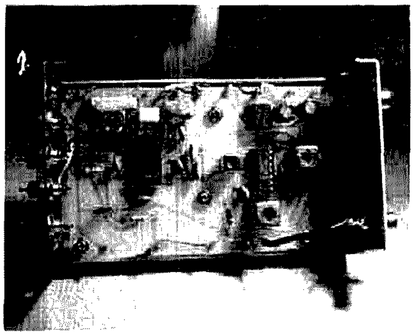


fig. 2. WA2PZO/Science Workshop i-f board built into shielded box.

*WA2PZO, *Science Workshop*, P.O. Box 393, Bethpage, New York 11714

The i-f board used in the W4UCH article and sold by Science Workshop is shown in **fig. 2**. The term "i-f" used here actually means a fixed frequency, single-conversion superheterodyne fm receiver tuned to 45.75 MHz (the tuner's i-f output frequency), and down-converted to the standard 10.7 MHz used for fm receiver i-f amplifiers. Because the i-f strip is actually a single-conversion receiver, the overall spectrum analyzer is a dual-conversion superhet. In fact, it can be used as a VHF receiver if the sweep is turned off (see *Sweep On/Off* in **fig. 3**).

The literature that came with the i-f board suggested that it be well shielded, and that feedthrough capacitors be used on all leads except the i-f input. The shielded enclosure is a standard chassis box with foldover flanges. Beware of many "shielded boxes" now on the market. The flanged type shown in **fig. 2** is minimally acceptable for shielded projects. The type of box that doesn't have overlapping flanges isn't acceptable at all. Some LMB boxes use little dimples on each edge for support, so they won't provide adequate shielding for most rf projects. While they're fine for audio and DC projects, they leave a great deal to be desired at rf.

Being an "older guy" in radio, I still called the feedthrough capacitors by that name and had a difficult time finding them locally; it seems that they're now called "EMI filters." Luckily, a local number for Newark Electronics was listed in the Yellow Pages, so I was

able to buy them directly from the source called for in the article.

In retrospect, "next time" I might try using a single connector for all leads other than the i-f, and 0.002-μF disk ceramic capacitors on each lead at the connector. A good chassis-mounted connector costs about $5 (or less), and high quality disk capacitors cost only about 80 cents each and even less per unit in bargain packs. The EMI filters called for in the article are about $4 each; about 12 are required.

adding a sweep circuit

A significant problem with the W4UCH article for many readers is the lack of a sawtooth circuit. W4UCH used the sawtooth output of his Heath OL-1 oscilloscope to sweep the tuner. That approach works if your oscilloscope provides this waveform. But modern oscilloscopes rarely have the sawtooth available on the front or rear panels. Also, many don't have a horizontal input. Look at your own oscilloscope's front panel. Some two-channel oscilloscopes have an "X-Y" mode on the vertical selector. If yours does, then one of the vertical channels can be re-configured as a horizontal channel at the flick of a switch.

If you don't have a horizontal input, or X-Y capability, you can still build the "Poor Man's Spectrum Analyzer" if you have either an "EXTERNAL TRIGGER" input (most 'scopes do) or a "TRIGGER GATE" output. The former allows an external signal, such as the falling edge of an external sawtooth, to trigger the sweep. The latter outputs a narrow pulse every time the oscilloscope triggers. By allowing the 'scope to self-trigger, you get a string of pulses that can be used to trigger certain types of sawtooth generators.

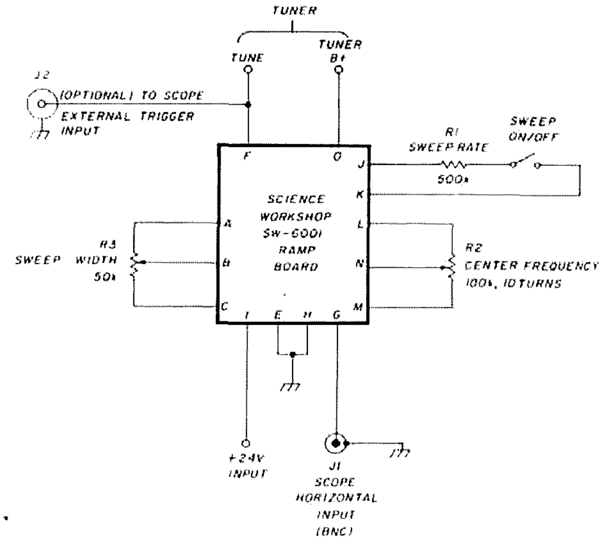


fig. 3. Sweep board SW-6001 connections (available from Science Workshop).

Science Workshop makes a board available (**fig. 3**) that can be used for generating and controlling an external sawtooth. Although it suffices at this point, I'm not totally happy with the design. As I see it, there are two problems (see **fig. 4**): first, the sawtooth isn't very linear (see **fig. 4A**), and its fall time is too long. Second, the sawtooth clips at various settings of the center frequency and sweep rate controls. Perhaps in the future I'll find time to re-design these circuits, but for now the sawtooth board is satisfactory.

dc power supply

The Poor Man's Spectrum Analyzer requires a two-voltage, single-polarity dc power supply: +12 VDC and +24 VDC. The schematic diagram of a power supply that meets these requirements is shown in **fig. 5**.

I used a pair of small 12.6-VAC transformers (T1 and T2), with the primaries connected in parallel and the secondaries connected in series, to obtain the required voltage. I used available components — a pair of brand-new *Radio Shack* pc-mount transformers. You can use instead either a 25.6-VAC transformer or a dual-secondary transformer stocked by Digi-Key,* Dick

*Digi-Key Corporation, P.O. Box 677, Thief River Falls, Minnesota 56701.

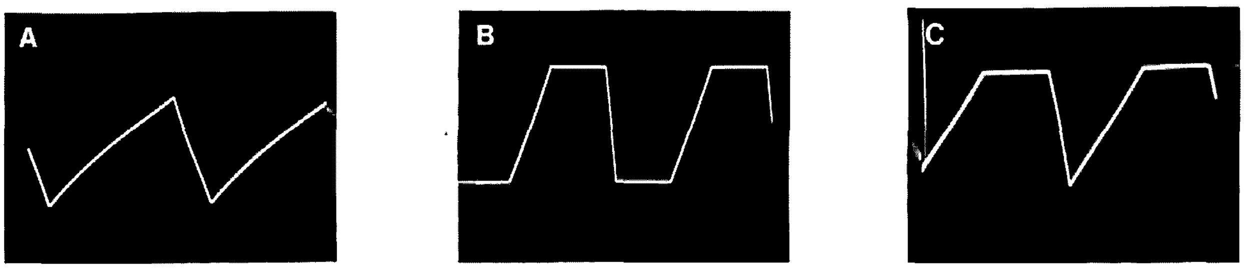


fig. 4. Waveforms from SW-6001: (A) Mid-range sawtooth, (B) and (C) are sawtooths taken at extremes of CENTER FREQUENCY and SWEEP RATE controls.

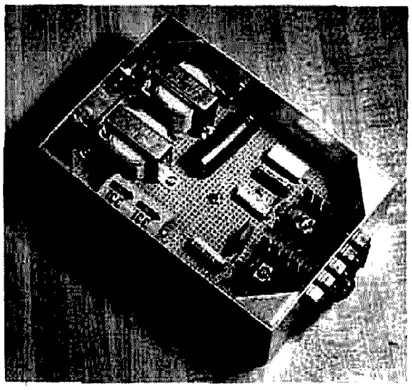


fig. 5A. DC power supply: top view of perf-mounted assembly.

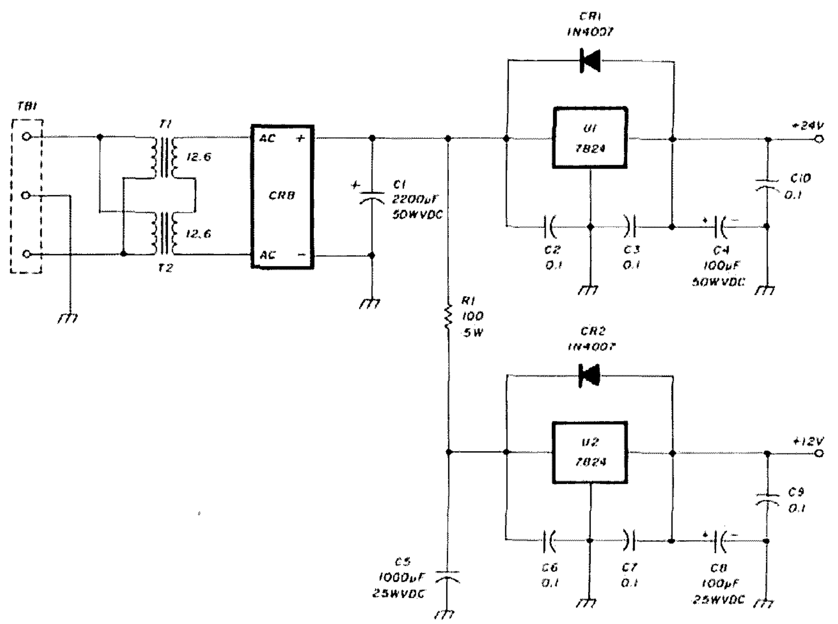


fig. 5B. DC power supply schematic.

Smith Electronics,** and other distributors. The current requirements for this project aren't critical, so almost any transformer with a rating of 300 mA or more is acceptable.

Two three-terminal IC regulators are used in this project. The 7824 (also usable: LM-340T-24) provides the needed +24 VDC, while a 7812 (or LM-340T-12) provides the +12 VDC. Both regulators are standard, but I found that the 7824 was a little hard to find locally. The NTR line of replacement semiconductors, stocked by many local distributors, carries a good replacement number.

There's nothing critical about the parts layout, and perf board can be used for construction. The diodes (CR1 and CR2) are used to prevent the charge in the output capacitors from damaging the voltage regulators at turn-off. Don't delete them, even though you may see many circuits using these regulators without charge dump diodes. The shielded construction and the 0.1-μF output capacitors are needed because one might be using this device in close proximity to a high-power transmitter. The capacitors must be mounted on the output terminal, or at least as close as physically possible.

performance

Figure 6 shows an oscilloscope photo of the spectrum analyzer display. The center frequency was adjusted to the low end of the fm broadcast band. The large center spike is the signal from my Measurements Model 80 signal generator set to approximately 85 MHz. The small spike to its right is WAMU-FM (88.5 MHz), my favorite public radio station; the other spikes are other fm band signals. The large signal barely visible on the left side is, I believe, Channel 5 TV in Washington, DC.

Those who don't have a horizontal input must use the sawtooth to trigger the sweep through the EXTERNAL TRIGGER input. I recommend using the negative trailing edge of the sawtooth waveform for this purpose (set TRIGGER SLOPE — or equivalent switch — to the negative position). Also, be sure to make the sweep time across the entire horizontal aspect of the 'scope graticule equal to the period of the sawtooth leading edge. Otherwise, the 'scope and sawtooth won't sweep in sync.

future projects

The spectrum analyzer project has given me a few ideas for changes or improvements. First, I plan to redesign the sawtooth generator (possibly generating the sawtooth digitally). Second, I plan to add an amplifier/attenuator based on Mini-Circuits fixed attenuators and a Signetics NE-5205 amplifier.[1] The range will be -60 to +19 dB. Third, there may be a converter for hf, and tuners to band-limit the spectrum analyzer at will to certain VHF Amateur bands. This modification will punch out certain local signals that tend to drive receivers into intermod problems at my QTH. Fourth, WA2PZO is working on a tracking oscillator circuit, and in fact has a tentative approach to its design. A tracking oscillator produces an output at the spectrum analyzer's center frequency. Besides its obvious use as a signal source, it's also useful for driving a frequency counter. Presently, tuning indication is by seat-of-the-pants calibration of the voltage control. I plan to buy the WA2PZO tracking oscillator kit if, and when, it becomes available.[3]

Varactor tuners are inherently nonlinear in their voltage-vs-frequency

**Dick Smith Electronics, P.O. Box 8021, Redwood City, California, 94063-8021.

fig. 6. FM broadcast band signals from my spectrum analyzer project. Central spike is a signal generator on 85 MHz ($\pm$ 25-year-old dial calibration).

characteristic and the resulting curve looks parabolic in shape. Digitally generating the sawtooth signal is a worthwhile consideration. If you want to try it yourself, write to me and I'll send you a brief on the method. (Please enclose a No. 10 SASE.) A very brief discussion of the digital linearization method is given on pages 300-302 of my book, *How to Design and Build Electronic Instrumentation.*[2] Although my method is based on discrete logic circuits, it can easily be applied to digital computers should you want to provide computer control of your spectrum analyzer.

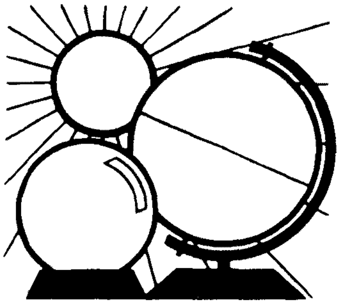
conclusion

WA2PZO deserves accolades (and our business) because of the Poor Man's Spectrum Analyzer project, which offers opportunity for experimentation in areas previously closed to Amateurs solely for reasons of cost. If you have an idea for its use, a new or different modification, or a particularly well-built version of the W4UCH/WA2PZO project, send me the details.

references

1. Michael E. Gruchalla, "NE-5205 Wideband RF Amplifier", *ham radio*, September, 1986, page 30.
2. Joe Carr, K4IPV, *How to Design and Build Electronic Instrumentation*, Second Edition, Tab Books, Blue Ridge Summit, Pennsylvania 17214. ($17.95 from the author, publisher, or Ham Radio's Bookstore, Greenville, New Hampshire 03048. Add $3.50 shipping and handling for HR Bookstore orders.)
3. For ideas on building your own, see also Wayne Ryder's "Spectrum Analyzer Tracking Generator," *ham radio*, September, 1978, page 30.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

equinox problems

Most of the year, strong, stable DX reception occurs when one operates close to the MUF (maximum usable frequency). There are, however, two seasons during which the ionosphere doesn't "cooperate." These are the equinoctal periods (from March through April and from September through October), when the Earth's geomagnetic field is anything but stable. This field guides ion diffusion and drift from the D, E, and lower F layers (where ionization occurs) up to the higher part of the F layer, the main region used for DX.

The geomagnetic field's variability is related to the characteristics of the solar wind. Variations in solar wind particles streaming out from the sun are passed on to the geomagnetic field. This in turn affects the ionosphere's ions and electrons — and, consequently, the propagated signals.

It's the alignment of the Earth's polar regions to the sun's spiraling solar wind (see fig. 1) that makes the equinox seasons troublesome. Subsequent ionospheric variations influence a signal's azimuthal and elevation angle of arrival as well as its amplitude and phase.

Paths that have high latitude (i.e., greater than 50 degrees north or less than 50 degrees south) reflection points are most affected; equatorial regions are less disturbed. Mid-latitude reflection points at about 25 through 50 degrees are the least affected and therefore the most stable. There is also a diurnal variation superimposed on this seasonal occurrence. This variation is divided into two parts: one, a period from midnight to 0400 *universal* time; and two, the period from 10 pm to 5 am, *local* time. Consequently, nighttime (from 10 pm to 5 am) is a more unstable time for everyone. The universal time segment, on the other hand, is different for each location, depending upon where (i.e, at which longitude) you live. If the two time periods overlap at your QTH, then the effects of the disturbed conditions are even greater. Such is the case for Amateurs who live between 75 degrees East and 150 degrees West longitude; unfortunately, this area encompasses Europe and the Americas. This effect is particularly potent along the east coast of the USA. On the positive side, this phenomenon often lets us work DX from unusual locations. Check WWV at 18 minutes after the hour for geomagnetic K figures of four to seven as a guide to the unusual DX openings.

last-minute forecast

DX conditions for the higher frequency bands, 10 through 30 meters, are expected to be excellent toward the end of the first week and through the second week of March. The favorable conditions are partly due to transequatorial openings at southeast through southwest headings.

From about March 6 through the 10th, expect some increase in solar flare SIDs (sudden ionospheric disturbance), which will appear as increased attenuation of signals for up to an hour during the daytime. A geomagnetic disturbance (signal attenuation and QSB, mainly at night) can be expected two to three days later. The same situation will occur during the third week of the month. The lower bands are more affected by these disturbances, but are still expected to be very good for evening and nighttime DX the third and fourth weeks of the month. Some thunderstorm QRN can be experienced as springtime weather fronts pass your QTH. Spring equinox occurs on March 21st at 0352 UTC. The moon is full on the 15th and at perigee on the 24th.

band-by-band summary

Ten, twelve, fifteen, and twenty meters provide many openings during the daytime. As you go up in frequency (i.e., into the higher bands) the openings will be shorter, centered around noon, and mainly toward southerly directions. Fifteen meters is now only a transition band between 12 and 20. Twenty meters, the mainstay daytime band, will be useful toward the south in the evenings for northerly directions. Transequatorial openings might occur in evening hours to locations up to 2000 miles if antenna radiation angles are down to 10 degrees.

Thirty, forty, eighty, and one-sixty meters are all good for nighttime DX. Thirty and 40 meters are the night frequencies for the east-west and northerly directions and for distances of 1600 miles if increased solar activity has occurred. With little solar activity, the MUF will approach 80 meters and signals will usually be stronger. These bands should generally be quiet, since thunderstorm activity is still not pronounced.

ham radio

MARCH

WESTERN USA

GMT	PST	N ↑ ASIA FAR EAST	NE ↗ EUROPE	E → S. AFRICA	SE ↘ S. AMERICA	S ↓ ANTARCTICA	SW ↙ NEW ZEALAND	W ← OCEANIA AUSTRALIA	NW ↖ JAPAN
0000	4:00	20	40	20	10	12	10	10	15
0100	5:00	20	40	20	10	12	10	10	15
0200	6:00	20	40	20	12	12	10	10	20
0300	7:00	20	40	20	12	12	10	10	20
0400	8:00	20	40	20	15	15	10	10	20
0500	9:00	30	40	20	20	20	12	12	30
0600	10:00	30	_40_	20	20	20	12	12	30
0700	11:00	40*	_40_	20	20	30	15	15	30
0800	12:00	40	_40_	_20_	20	30	20	20	40
0900	1:00	40	_40_	_30_	_20_	_30_	20	20	40
1000	2:00	_40_	_40_	_30_	_20_	_30_	20	20	40
1100	3:00	_40_	_40_	_30_	_20_	_30_	_20_	20	40
1200	4:00	_40_	30	20	_20_	_30_	_20_	_20_	_40_
1300	5:00	_40_	20	12	20	_30_	_20_	_20_	_40_
1400	6:00	30	20	10	15	40*	_30_	_20_	_40_
1500	7:00	30	20	10	12	20	_30_*	_20_	_40_
1600	8:00	40	20	10	10	20	_30_	_20_	_40_
1700	9:00	40	20	10	10	15	20	_20_	_40_
1800	10:00	40	20	10	10	15	20	_20_	_40_
1900	11:00	_40_	20	10	10	12	15	20	20
2000	12:00	_40_	20	12	10	12	12	15	20
2100	1:00	_40_	30	12	10	12	12	12	20
2200	2:00	_40_	30	15	10	12	10	12	20
2300	3:00	20	40	20	10	12	10	10	15

MID USA

GMT	MST	N ↑ ASIA FAR EAST	NE ↗ EUROPE	E → S. AFRICA	SE ↘ S. AMERICA	S ↓ ANTARCTICA	SW ↙ NEW ZEALAND	W ← OCEANIA AUSTRALIA	NW ↖ JAPAN	CST
0000	5:00	40	40	20	10	12	10	10	15	6:00
0100	6:00	30	40	20	12	12	10	10	20	7:00
0200	7:00	30	40	20	12	15*	10	10	20	8:00
0300	8:00	30	40	20	15	15	10	10	20	9:00
0400	9:00	40	40	20	20*	15	12	12	30	10:00
0500	10:00	40	_40_	20	20	20	12	15	30	11:00
0600	11:00	40	_40_	20	20	30	15	20	30	12:00
0700	12:00	40	_40_	_20_	20	30	20	20	40	1:00
0800	1:00	_40_	_40_	_30_	_20_	_30_	20	20	40	2:00
0900	2:00	_40_	_40_	_30_	_20_	_30_	20	20	_40_	3:00
1000	3:00	_40_	30	_30_	_20_	_30_	_20_	_20_	_40_	4:00
1100	4:00	_40_	20	15	_20_	_30_	_30_	_20_	_40_	5:00
1200	5:00	20	20	12	20	_30_	_30_	_20_	_40_	6:00
1300	6:00	20	20	10	15	_30_	_30_	_20_	40	7:00
1400	7:00	20	20	10	12	20	_20_	20	40	8:00
1500	8:00	20	20	10	10	20	_20_	_20_	_40_	9:00
1600	9:00	30	20	10	10	15	_20_	_20_	_40_	10:00
1700	10:00	40	20	10	10	15*	20	_20_	_40_	11:00
1800	11:00	40	20	10	10	12	20	_20_	_40_	12:00
1900	12:00	40	20	10	10	12	15	20	20	1:00
2000	1:00	_40_	20	12	10	12	12	15	20	2:00
2100	2:00	_40_	30	12	10	12	12	12	20	3:00
2200	3:00	_40_	30	15	10	12	10	10	20	4:00
2300	4:00	_40_	40	20	10	12	10	10	20*	5:00

EASTERN USA

GMT	EST	N ↑ ASIA FAR EAST	NE ↗ EUROPE	E → S. AFRICA	SE ↘ CARIBBEAN S. AMERICA	S ↓ ANTARCTICA	SW ↙ NEW ZEALAND	W ← OCEANIA AUSTRALIA	NW ↖ JAPAN
0000	7:00	30	40	20	10	12	10	10	20
0100	8:00	30	40	20	12	12	10	10	20
0200	9:00	30	40	20	12	15	12	12	30
0300	10:00	40	40	20	15	15	15	15	30
0400	11:00	40	_40_	20	20	20	20*	20	30
0500	12:00	40	_40_	_20_	20	20	20	20	40
0600	1:00	_40_	_40_	_20_	_20_	_30_	20	20	_40_
0700	2:00	_40_	_40_	_20_	_20_	_30_	_20_	20	_40_
0800	3:00	_40_	_40_	_20_	_20_	_30_	_20_	20	_40_
0900	4:00	_40_	30	_20_	_20_	_30_	_30_	_20_	_40_
1000	5:00	20	20	15	_20_	_30_	_30_	_20_	_40_
1100	6:00	20	20	12	_20_	_30_	_20_	_30_	40
1200	7:00	20	20	10	15	_30_	_20_	_20_	40
1300	8:00	20	20	10	15*	20	_20_	20	40
1400	9:00	20	20*	10	12	20	_20_	_20_	40
1500	10:00	30	20	10	10	20*	_30_	_20_	_40_
1600	11:00	30	20	10	10	15	20	_20_	_40_
1700	12:00	40	20	10	10	15	20	_20_	_40_
1800	1:00	40	20	10	10	12	20*	_20_	_40_
1900	2:00	40	20	10	10	12	15	20	30*
2000	3:00	_40_	20	10	10	12	12	15	20
2100	4:00	_40_	30	12	10	12	12	12	20
2200	5:00	_40_	40	15	10	12	10	10	20
2300	6:00	_40_	40	20	10	12	10	10	20

The _italicized numbers_ signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

product
REVIEW

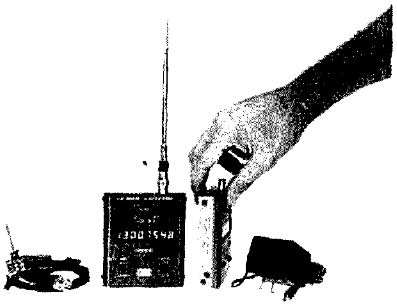
OPTO 1.3 GHz shirt pocket frequency counter

A friend has something he calls his "$4000 gutbuster." A sixties-vintage 1-MHz Beckman-Berkeley nixie tube digital frequency counter, it claims a fair plot of acreage in his closet-sized ham shack, sitting atop a $2000 gutbuster and supporting a $5000 gutbuster — all treasures acquired, long past their prime, for a few dollars each at some long-forgotten flea market.

For those of us who grew up with solid-state equipment (and therefore take it pretty much for granted), OPTO's new 1.3 GHz shirt pocket frequency counter is impressive in terms of size (3-1/2 x 4 x 1 inches), cost ($99.95 in kit form), maximum frequency (1.3 GHz), and sensitivity. For our friend, it's nothing short of miraculous.

Operating from either ac or a 9-volt internal rechargable NiCAD battery pack, the Model 1300 covers 1 through 1300 MHz. Though we didn't have the opportunity to check it out on the 1296-MHz band, it worked like a champ on 2 meters and hf.

The OPTO counter sports two switch-selected sensitivity ranges. In the high range with the optional telescoping antenna attached, front end gain causes a continuous spurious count that's easily identified by the randomizing of the three or four least significant digits. In the presence



of even a weak signal (i.e., for a counter), the count stabilizes and you know the unit's working. In one quick test, the counter performed faultlessly on a handheld unit pushing 500 mW into a rubber duck over distances up to about 50 feet through an exterior (wooden) wall.

In addition to two sensitivities (with accuracy said to be within ±1 count LSD, thanks to an RTXO time base), the counter offers two gate periods, 0.25 and 2.5 seconds. (As with *any* counter, if the source either comes on or goes off during the gate period, the count will be incorrect).

Both the mechanical and electronic quality of the OPTO counter are excellent. Housed in a sturdy anodized aluminum case — which, by the way, you don't have to open to adjust calibration — it has endured several months' careless handling without complaint. Eight bright red 0.28-inch LEDS make reading it easy, even under a variety of difficult lighting situations.

Priced at $150 assembled, it's also available in kit form for $99.95. Both the finished unit and kit include NiCads and a 110 VAC/9 VDC adapter for ac operation and charging. Optional accessories include a carrying case, probe, and the abovementioned telescoping antenna.

For details, contact OPTOelectonics, Inc., 5281 Northeast 14th Avenue, Fort Lauderdale, Florida 33334.

— KA1LBO

Circle #301 on Reader Service Card.

NEW products

orbital predictions

Project OSCAR, Inc. is preparing a new set of orbital predictions for 1987. The predictions will provide the UTC times and longitude for all south-to-north equatorial crossings of the two active Russian satellites carrying Mode A transponders (RS5 and RS7), the two University of Surrey-AMSAT scientific satellites (O9 and O11), and the recently launched JARL/JAMSAT satellite, JAS-1, recently renamed Fuji OSCAR 12 (FO12), which carries both analog and digital Mode J transponders.

Used with the appropriate plotter, these predictions allow the user to determine the access times to all presently available Amateur Radio satellites. The cost in the U.S., Canada, and Mexico is $10 ($12 for overseas).

For details, write Project OSCAR Inc., P.O. Box 1136, Los Altos, California 94023-1136.

Circle #311 on Reader Service Card.

6- and 8-pole crystal filters

IRI has announced the addition of 14 new 6- and 8-pole crystal filters designed for both general experimental use and for use in recent Kenwood and ICOM hf transceivers and receivers. These filters vary in bandwidth from 250 Hz to 2.2 kHz. Kenwood and ICOM filter models range in price from $99 to $125. The 6-pole experimenter's filters are priced at $50; the 8-pole filters, $60.

For details on models and specifications, contact International Radio, Inc., 747 South Macedo Boulevard, Port St. Lucie, Florida 33452.

Circle #310 on Reader Service Card.

NEW products

ultra-compact VHF transceiver

ICOM's new IC-275 is a new ultra-compact all-mode VHF transceiver that's jam-packed with all the most wanted features. It boasts 25 watts (the IC-275A includes a built-in power supply) or 100 watts (IC-275H with an external optional power supply) output, 99 tunable memories, wideband receive coverage from 138-174 MHz (Tx from 140.100-150.000 MHz), 32 built-in subaudible tones (actual subaudible frequency is displayed), odd offset capability, and a call channel.

/ Ideal for satellite operation, it also features full scan of the entire frequency spectrum, program scan, memory scan (20 memories in only 1 second), memory lock-out in scan function, and mode scan.

The packet-compatible IC-275 incorporates a data switch for 5-ms switching time, a new velvet-touch tuning knob, and an easy-to-read amber LCD readout. It comes ready to operate with an HM-12 up/down scanning mic and dc cord.

Options include a tone squelch unit, speech synthesizer, a module for OSCAR operation that allows tracking with its new IC-475 UHF companion and an FL-83 500 Hz 10.7491 MHz CW filter. The AG-25 mast-mounted preamp is also available.

The IC-275A is priced at $1199.

ICOM America, Inc., 2380-116 Avenue, N.E., P.O. Box C-90029, Bellevue, Washington 98009-9029.

Circle #309 on Reader Service Card.

international satellite receiver

The AVCOM COM-3R International is a high-performance receiver designed for easy operation plus powerful and versatile earth station receiver capabilities.

Special threshold extension circuitry is used in the COM-3R International to enable it to produce high-quality video, even in the fringes of a satellite footprint. For international reception, optional threshold peaking and selectable triple i-f filters, optimized for this purpose, are available.

For details, contact AVCOM of Virginia Incorporated, 500 Southlake Boulevard, Richmond, Virginia 23236.

Circle #302 on Reader Service Card.

hand set and phone patch

NCG's Hotline 107 Hand Set, developed in response to requests from both Amateurs and Land Mobile radio users, includes the following features: a dynamic 100-ohm speaker, adjustable volume control, in-cradle dialing, vertical or horizontal mounting, and a noise-cancelling microphone. Model 107M's features include all of the above plus auto-dial, 10-number memory, super-capacitor-based 14-day memory backup, plus 3-button memory set, storage, and recall. ANI is installable by the system's owner.

Features of the new Hotline-007 MK III, already one of the best selling phone patches, include all-mode operation (a-m, fm, SSB), easy hookup (no internal wiring is required to the base), a dial restrict switch (to inhibit 0 and 1, preventing unauthorized long distance calls), and owner-programmable access code and CW ID.

New features include a manual connect/disconnect switch. More importantly, the MK III is switchable from simplex to full duplex, which greatly improves the quality of phone conversations and increases the Hotline's versatility. Besides use as a phone patch, it can be used as a repeater interconnect and a quick field mini-repeater.

Both units are available through independent dealers or through the manufacturer. For details, contact NCG Company, 1275 N. Grove Street, Anaheim, California 92806.

Circle #308 on Reader Service Card.

KDK FM-240 service manuals

Service manuals for the Encomm FM-240 are now available. The technical manual — plus an updated version of the owner's manual, schematic diagram, and board layouts — are included in a hardbound notebook for easy access. The suggested retail price is $15.95.

For details, contact Encomm, Inc., 1506 Capital, Plano, Texas 75074.

Circle #320 on Reader Service Card.

pocket digital multimeter

Eaglestone, the new direct marketing division of Siber Hegner North America, offers a card-size digital multimeter with increased voltage and ohm ranges to 500 volts ac/dc and 20 megohms, respectively. Model DM1000 folds to approximately 4.5 x 3 x 0.5 inches and weighs only 3 ounces.

Complete with velcro-attached probes, the DM1000 offers 0.7 percent basic dc accuracy, autoranging, diode testing and an easy-to-read LCD. During wiring checks, a tone sounds to indicate continuity. A single rotary switch immediately accesses all functions — dc or ac volts, ohms, and continuity/diode.

Model DM1000 sells for $35 with a risk-free, 30-day money-back return and a full one-year warranty. For details, contact Eaglestone, 5 Landmark Square, Stamford, Connecticut 06901.

Circle #307 on Reader Service Card.

service monitor

CT Systems of Beech Grove, Indiana, has introduced the Model 3100 Communications Service Monitor, which includes such features as duplex/offset generation, spectrum analysis, sweep testing, filter alignment, cellular testing, and tone/digital signalling — all in a lightweight, compact unit. Simple to operate, the unit offers built-in "real time" self-diagnostics, SINAD, dc and ac oscilloscope, RMS ac voltmeter, DTMF and digital coded squelch, and other features. Priced at $9,650, the 3100 can store 20 complete sets of instrument parameters, allowing radio data and various test conditions to be saved into memory.

For details, contact CT Systems, Inc., 5245 Hornet Avenue, Beech Grove, Indiana 46107.

Circle #303 on Reader Service Card.

new rf power meter

Bird Electronic Corporation has announced the release of its Model 4421 RF Power Meter, a programmable, microprocessor-based instrument which measures forward and reflected rf power, VSWR, and return loss in watts or dBm. The model 4421's accuracy is ±3 percent of the reading. The 4421 package includes a new remote sensor head based on Bird's proven Thruline® principles for in-line, unterminated measurements to 1kW without the need for directional couplers or attenuators.

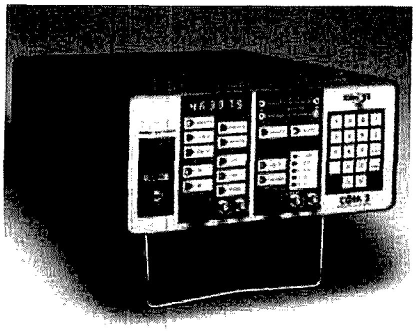
The frequency range of 1.8 MHz to 1 GHz is covered by only two sensors for fast, flexible operation. Each sensor carries its own calibration profile in a reprogrammable memory. Bird plans other sensors to extend the measurement range into the milliwatt and microwatt region. Optional interfaces provide for remote, programmed operation. Under control of a personal computer, the 4421 can both acquire and store data. Other highlights include simple front panel operation with push-button function selections and auto or manual ranging.

The model 4421 RF Power Meter is priced in the $2,000-$3,000 range, depending on accessories. For more information on the 4421 or other Bird products, contact Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon), Ohio 44139.

Circle #304 on Reader Service Card.

portable communications service monitor

Ramsey Electronics' new COM-3 Service



Monitor, designed for analyzing and testing transceivers in the 100-kHz to 1000-MHz range, features a programmable microprocessor memory that stores and recalls up to ten commonly used test set-ups. It covers every band and frequency, and i-f parameters of 100 kHz to 1000 MHz in 1 kHz steps. The keyboard features programmable offset keys that simplify frequency entry for duplex or repeater radios, and incremental step keys to facilitate receiver testing.

The COM-3 monitor weighs less than 10 pounds and has a built-in, rechargeable battery pack. A Cordura travel case with zippered pockets and shoulder strap is optional.

The manufacturer's introductory list price for the COM-3 is $1995. For details, contact Ramsey Electronics Inc., 2575 Baird Road, Penfield, New York 14526.

Circle #305 on Reader Service Card.

new shortwave "sloper"

Universal Shortwave's new Alpha Delta DX-SWL Sloper Antenna covers medium-wave and all major shortwave bands, as well as the 90- and 120-meter bands, often overlooked by dipole antennas.

The overall length of the slope wire is 60 feet. It includes a single 50-ohm coaxial feedpoint (for PL259) at the apex for user-supplied 50-ohm coaxial lead-in. The American-made DX-SWL Sloper, constructed with heavy-duty components and stainless steel hardware, utilizes broadband low-*Q* rf choke resonators for multiband frequency selection. It is fully assembled and requires no adjustments or "trimming"; only one end of the antenna needs to be elevated (25 feet or higher). The price is $69.95 plus $2.75 for shipping and handling.

For information, contact Universal Shortwave, 1280 Aida Drive, Reynoldsburg, Ohio 43068.

Circle #306 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

HOT/NEW PACKET PROGRAMS FOR YOUR IBM PC. Several telecommunications programs to choose from, especially written to interface your packet controller with your PC or compatible/clone. Features like Full Screen, Line Screen editing. Split Screens, ASCII, Binary, X Modem or user defined file transfers, DOS shell, Macro Keys, Command Files, many types of time/date/oper. ID. Multi-page brochures explain them all. Software Support. Write for new information and pricing. KALT & ASSOCIATES, 2440 E. Tudor Rd, Suite 138, Anchorage, AK 99507. (907) 248-0133. Charge Cards accepted.

S.S.B. CRYSTAL FILTERS. 9.0 MHz, 2.2 kHz bandwidth, six pole, with data $20.00 postpaid. OEM quantity available. ICL7117 D V M. I.C.'s direct drive 3-1/2 digit LED same as 7107 plus hold, with data; $6.00. 2/$10.00 postpaid. Dentron Scout C A.P. transceiver, 4 MHz, 100 watts, new; $250.00. A.C P.S. $75.00 postpaid. George Misic, 14481 Watt, Novelty, Ohio 44072.

HF WEFAX for use with most personal computers. For info SASE to A & A ENGINEERING, 2521 W. LaPalma Ave, #K, Anaheim, CA 92801. (714) 952-2114.

LEARN MORSE CODE IN 1 HOUR. Amazing new easy technique. Moneyback guarantee. $10. Bahr, 2549H Temple, Palmbay, FL 32905.

SUPERFAST MORSE CODE SUPEREASY. Subliminal cassette. Moneyback guarantee. $10. Bahr, 2549H Temple, Palmbay, FL 32905.

TEN-TEC now shipping new-boxed USA made latest 1987 factory models Corsair II, Century 22, Argosy II transceivers. Titan linear amplifier 229A 2kw antenna tuner plus accessories, antenna. For the best Ten-Tec deal write or phone Bill Slep (704) 524-7519, SLEP ELECTRONICS COMPANY, Highway 441, Otto, NC 28763.

WANTED Schematic for Bearcat 100 Electra, Model BC-100 Scanner. Please contact Ralph E. Smith, 857 Rougemont, St. Foy, Quebec City, Canada.

HEATH Deluxe antenna tuner Model SA2060 - a beauty - best offer. (401) 789-1817 FOB.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

COLLINS KWM-380. Fully updated. Excellent condition. Full service manual. Write or call. W3IRE, 9436 Howes Road, Dunkirk, MD 20754. (301) 257-3041.

BACK ISSUES OF HAM RADIO Magazine from March 1968 to June 1974. Complete your collection. Individual issues $4.00 each. KX9P (319) 377-3563.

IBM/APPLE COMPUTER program "Hamlog". 18 modules logs auto sorts 7-band WAS/DXCC. Full feature. Also CP/M. Apple $19.95, IBM $24.95. HR-KA1AWH, PB 2015, Peabody, MA 01960.

LO COST Sensitive-Selective HF receiver system. Ideal/1st station set. Enhanced Novice 10/15/40/80m coverage. Send 2 stamps for free info. I. Megeff, KD2EF, 729 Lori Drive #101, Palm Springs, FL 33461.

HOBBY, EDUCATIONAL, INDUSTRIAL PRODUCTS. 70 kits. Amplifier, FM transistor, VU meter, door bell, alarm system, power supply. Send $3.00 to HOBBY ELECTRONIC, PO Box 1339, Claremont, NH 03743 or call (603) 543-0033.

COLLECTORS: Have Karl Pierson KP-81 communications receiver for sale. Complete system: receiver, speaker cabinet and book. Open to offers. Cal, KL7HEM, 10300 Silver Knolls, Reno, NV 89506.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

TRS80 4P/KANTRONICS UTU RTTY. Split screen, 10 user keys, file transfer. Runs in Mod 4 (80 char) mode. $30 to COMMPRO RTTY, c/o KB6IC, 3711 Gayle Avenue, Omaha, NE 68123.

SOLAR ELECTRIC PANELS and System Components. 1st quality for home or repeaters. Lowest prices in country. KA8DSS, RADIANT DISTRIBUTORS, 3900 Dursum, Ada, MI 49301. (616) 874-8899.

WA9GFR
RF SOFTWARE $15.00 disk contains HF/VHF/UHF/L-BAND propagation and Smith Chart impedance matching programs. Specify Commodore-64 or MS-DOS BASIC. Lynn Gerig, 6417 Morgan RD, Monroeville, IN 46773.

REMEMBER TROLLEY CARS? *Trolley Treasures: The War time Years in New Jersey* (1939-1947), a 4 volume photodocumentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

UHF PARTS. GaAs Fets, MMICs, trimmers, chip caps, teflon pcb, and other builder parts. SASE brings list. MICROWAVE COMPONENTS, 11216 Cape Cod, Taylor, MI 48180.

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

YAESU OWNERS: Hundreds of modifications and improvements for your rig. Select the best from fourteen years of genuine top-rated Fox-Tango Newsletters by using our new 32-page Cumulative Index. Only $5 postpaid (cash or check) with $4 Rebate Certificate creditable toward Newsletter purchases. Includes famous Fox-Tango Filter and Accessories Lists. Milt Lowens, N4ML (Editor), Box 15944, W. Palm Beach, FL 33416. Telephone (305) 683-9587.

RTTY JOURNAL - Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Aye., Fountain Valley, CA 92708.

IMRA *International* Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, New York 10538.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: *Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc., are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.*

FLORIDA: March 21-22. The Playground Amateur Radio Club's 17th annual North Florida Ham/Swapfest, Shrine Fairgrounds, north Ft. Walton Beach. Doors open 8 AM both days. FCC exams Saturday only. ARRL, MARS, and QCWA meetings. Banquet Saturday night. RV parking. Talk in on 146.19/79 and 52. For more information write PARC, PO Box 873, Ft. Walton Beach, FL 32548.

GEORGIA: March 7. The Dalton Amateur Radio Club's 5th annual Hamfest, North Georgia Fairgrounds, Dalton. Indoor flea market with tables provided for sellers/traders. VE upgrade exams nearby. For information: DARCI, PO Box 143, Dalton, GA 30722-0143.

ILLINOIS: March 29. LAMARSFEST '87 sponsored by the Libertyville and Mundelein Amateur Radio Society. Lake County Fairgrounds, Grayslake. Doors open 8 AM. Commercial setup time (by reservation only) 6 AM. Admission $2.00 advancy by March 20; $3.00 at the door. Indoor swapfest, exhibitors, code speed testing and exams, free parking, public cafeteria. Talk in on 147.63-.03 Waukegan repeater. 146.52 simplex. For information and reservations: Lamars c/o Marc Abramson, PO Box 751, Libertyville, IL 60048. (312) 255-0642 8PM to 10PM CST.

ILLINOIS: March 15. The Chicago ARC will hold a continous seminar entitled "Introduction to Amateur Radio", Noon to 5 PM, North Park Village, Community Room, 5801 N. Pulaski Rd, Chicago. The Amateur Radio Novice Class license seminar will start Monday, March 16 at 7:30 PM, same address in "J" building. For information call (312) 545-3622.

KENTUCKY: March 28 and 29. LTARC Hamfest sponsored by the Lincoln Trail ARC, Pritchard Community Center, Elizabethtown. Admission $5.00 advance; $6.00 at the door. Dealer tables $10.00/day or $15.00 both days. Flea market $5.00/day or $8.00 both days plus admission ticket. Activities include ARRL State Convention, Walk-in testing, numerous forums. Free parking. Nearby motels, reasonable rates. Talk in on 146.52, 146.38/98. For tickets or reservations: Hubert Hensley, WD4GDA, PO Box 342, Vine Grove, KY 40175. Tel (502) 877-2234.

KENTUCKY: March 7. The annual Glasgow Swapfest will be held at a NEW LOCATION, the Cave City Convention Center, Cave City. Starts 8 AM, ends when everyone goes home. Admission $3.00 per person with no extra charge for exhibitors. Activities include DX and ARRL forums, flea market. FCC VE tests beginning 10 AM. Walk-ins only. Bring original license and photocopy. Talk in on 146.34/94 and 144.59/145.19. For more information: N4HCO, Rt 9, Box 112B, Glasgow, KY 42141.

MARYLAND: March 28 and 29. The Baltimore Amateur Radio Club will present the Greater Baltimore Hamboree and Computerfest, Maryland State Fairgrounds Exhibition Complex at Timonium. Indoor flea market and large dealer display area. Amateur radio, personal and small business computers featured. Hard surfaced outdoor flea market area. Food service, plenty of free parking and more. Gates open 8 AM each day. Admission $4.00/day or $6.00/both days. Children under 12 free. For additional information and display space reservations: GBH&C, PO Box 95, Timonium, MD 21093-0095 or call (301) HAM-FEST.

MICHIGAN: March 21. The Michigan Crossroads Hamfest. Sponsored by the Southern Michigan Amateur Radio Society and the Marshall High Photo Electronics Club. 8 AM to 3 PM. Marshall High School, Marshall, MI. Tickets $2.00 advance SASE; $3.00 at the door. Packet radio demonstration and forum, free parking, full food service. License exams Novice thru Extra. Preregistration requested. Send Form 610, SASE and $4.25 payable to ARRL/VEC to License Exam, PO Box 2, Pleasant Lake, MI 49272. Walk-ins on availability basis. Talk in on 146.67 or 146.52 or 223.94. For more information SASE to Louis Ryason, WB8WXS, 23 So. 27th Street, Battle Creek, MI 49015.

MICHIGAN: April 5. The South Eastern Michigan Amateur Radio Association's 29th annual Hamfest Swap and Shop, 8 AM to 3 PM, Grosse Pointe North High School, 707 Vernier Road, Gross Pointe Woods. ARRL, DX and Packet forums. Tickets $1.00 advance; $3.00 at the door. Tables $8.00 advance; $10.00 at the door. Talk in on SEMARA repeater 147.70/10 and 146.52 simplex. For information: SEMARA Hamfest, PO Box 646, St. Clair Shores, MI 48080 or phone Fred Lweis, NK8M (313) 881-0187.

MINNESOTA: April 4. 10th annual Rochester Area Hamfest sponsored by the Rochester ARC, John Adams Junior High School, 1525 NW 31st Street, Rochester. Doors open 8:30 AM. Large flea market, speakers, programs, refreshments and plenty of free parking. Talk in on 146.22/82. W0MXW. For further information contact: RARC c/o WB0YEE, 2253 Nordic Ct. NW, Rochester, MN 55901.

MISSOURI: March 13. The Jefferson Barracks Amateur Radio Club's 27th annual Amateur Radio Auction, Concordia Turners Hall, 6432 Gravois, south St. Louis City. Starts 7:30 PM.

NEW HAMPSHIRE: March 14. The Interstate Repeater Society of Derry, NH will hold its annual Flea Market, Lions Club Hall, Lions Avenue, Hudson. Doors open 8 AM. Admission $1.00 at the door. Tables $8.00 each. For table reservations (603) 623-0628 or (603) 883-9441. Write I.R.S., PO Box 693, Derry, NH 03038.

NEW JERSEY: March 28. Ham Radio Flea Market sponsored by the Chestnut Ridge Radio Club, Education Building, Saddle River Reformed Church, East Saddle River Road and Weiss Road, Upper Saddle River. Admission $1.00. Tables $10/first. $5.00 each additional. Tailgating $5.00. Contact Jack Meagher, W2EHD (201) 768-8360.

NEW JERSEY area Chaverim, an organization of Jewish Amateur radio operators completing its 4th successful year, invites all hams and those interested in Amateur Radio to join, particularly those in Monmouth and Ocean counties of NJ. We meet the first Sunday of the month in the Jewish Community Center, Grant Avenue, Deal. Write POB 192, West Long Branch, NJ 07764.

NEW JERSEY: March 22. HAMCOMP '87, 15th annual flea market sponsored by the Delaware Valley Radio Association. 8 AM to 2 PM, the New Jersey National Guard 112th Field Artillery Armory, Eggerts Crossing Road, Lawrence Township (Trenton) 2 miles north of I-95. Admission $3.00 advance; $4.00 at the door. Indoor selling space $10.00 (wall space) and $7.00. Outdoor spaces $6.00. Sellers bring own tables. Doors open for setup 6 AM. General public 8 AM. Free parking. Re-

freshments available. Talk in on 146.07 .67. For more information and space reservations; HAMCOMP '87, c/o KB2ZY, Box 441B, RD 1, Stockton, NJ 08559. Please SASE.

NEW JERSEY: March 13. The Splitrock Amateur Radio Association's 2nd annual Evening Hamfest, Drew University Center, Room 107, Rt. 24, Madison. Setup 6 PM. Doors open 7 PM. Admission for buyers $2.00. Tables available from $2.00 to $8.00 per table. Talk in on 146.985 outside Madison area. 146.58 in Madison area. For information write SARA, PO Box 3, Whippany, NJ 07981 or call Steve Halliburton, WA2SOC (201) 366-9642.

NEW JERSEY: March 28. The Shore Points ARC invites everyone to Springfest '87. 9 AM to 2 PM. Atlantic County 4 H Center, Rt. 50, Egg Harbor City, approx. 15 miles west of Atlantic City. Indoors, heated. Sellers $5 per space, bring own tables. Buyers $3. Outdoor tailgating, weather permitting. Food and drink available. Talk in on 146.985 and .52. For information write SPARC, PO Box 142, Absecon, NJ 08201.

OHIO: April 24, 25, 26. DAYTON HAMVENTION.

The Dayton Amateur Radio Association is now accepting applications for its 1987 Scholarship Program. Any licensed Amateur graduating from high school in 1987 is eligible to enter. For information and application forms write DARA Scholarship Committee, 317 Ernst Avenue, Dayton, Ohio 45405. OHIO: April 24. The 18th annual B¢A¢S¢H¢ will be held on FRIDAY NIGHT of the Hamvention, at the Conference Center (Madison Room) of the HARA ARENA AND CONFERENCE CENTER, (the same location as the Hamvention) starting at 7:00 PM. There is no admission charge, and free continuous entertainment. Hot dinner, sandwichs, snacks and beverages are available. Two exciting top awards, and many others. Stay right at HARA when the Hamvention closes on Friday evening *and meet your friends and join us for an evening of fun and entertainment*. Sponsored by the Miami Valley FM Association, PO Box 263, Dayton, Ohio 45401

PENNSYLVANIA: March 15. The Beaver Valley Amateur Radio Association's third annual Tri-State Hamfest. 8 AM to 4 PM. Community College of Beaver County "Golden Dome", Monaca. All indoors. Amateur license testing, forums, refreshments. Free vendor spaces. Table rental available. Talk in on 145.31/.71 W3SGJ/R and .52. Contact Mike Pastorik, KA3JRR, 115 West Woodland Drive, Aliquippa, PA 15001.

TEXAS: March 14. The Midland Amateur Radio Club will hold its annual St. Patrick's Swapfest, 10 AM to 5 PM, Midland County Exhibit Building, Highway 80, east of Midland. Preregistration $5.00, $6.00 at the door. Tables $6.00 each. Refreshments and food available. VE tests for all categories. For further information and reservations: Midland ARC, PO Box 4401, Midland, Texas 79704.

WEST VIRGINIA: April 5. Charleston WV Area Hamfest and Computer Show in Charleston Civic Center. 8 AM to 5 PM. Admission $4.00. Forums, SSTV, Packet, Flea Market and Swap Tables. Computer demos, ARRL booth. Talk in on 6.28/6.88. For information: Ollis Rinehart, KA8TIK, 1258 Ridge Drive, South Carleston, wV 25303. (304) 768-9534.

WISCONSIN: March 7. The Milwaukee School of Engineering ARC, W9HHX, will hold its annual Hamfest. 8 AM to 2 PM. 1121 N. Milwaukee Street, downtown Milwaukee. Tickets $2.00. 4' tables $3.00. Talk in on 146.19/146.79 and 146.52. For information, tickets or tables: SASE to W9HHXFEST, POB 644, Room C-6, Milwaukee, WI 53201-0644

WISCONSIN: March 22. The Tri-County ARC, W9MQB, will hold its annual Hamfest. 8 AM to 3 PM, Jefferson County Fairgrounds, Jefferson. Tickets $2.50 advance; $3.00 at the door. Tables $3.00 advance; $4.00 at the door. Plenty of FREE parking. *Amateur exams by the Milwaukee Volunteer Core Group.* Doors open at 7 AM for sellers. Talk in on 144.89/145.49 or 146.52. For more information, tickets or tables SASE to Bob Barker, K9RIJ, 724 Burdick, Milton, WI 53563.

WISCONSIN: April 5. The Madison Area Repeater Association, (M.A.R.A.) is please to announce its 15th annual Madison Swapfest, Dane County Exposition Center Forum Building, Madison. Doors open 7:30 AM for flea market sellers and 8 AM for the general public. An all-you-can-eat pancake breakfast available at the Swapfest. Admission $2.50 advance and $3.00 at the door. Children twelve and under admitted free. Flea market tables $5.00 each/advance and $6.00/door plus admission. The deadline for tickets and table reservations is March 31, 1987. For tickets, tables or information write M.A.R.A., PO Box 3403, Madison, WI 53704 or call (608) 274-5153 day or night

Foreign Subscription Agents for Ham Radio Magazine

Ham Radio Austria
Karin Ueber
Postfach 2454
D-7850 Loerrach
West Germany

Ham Radio Belgium
Stereohouse
Brusselsesteenweg 416
B-9218 Gent
Belgium

Ham Radio Holland
Postbus 413
NL-7800 AK Emmen
Holland

Ham Radio Europe
Box 2084
S-194 02 Upplands Vasby
Sweden

Ham Radio France
SM Electronic
20 bis, Ave des Clarions
F-89000 Auxerre
France

Ham Radio Germany
Karin Ueber
Postfach 2454
D-7850 Loerrach
West Germany

Canada
Send orders to
Ham Radio Magazine
Greenville, NH 03048 USA
Prices in Canadian funds
1 yr. $41.85, 2 yrs. $74.25
3 yrs. $99.90

Ham Radio Italy
Via Maniago 15
I-20134 Milano
Italy

Ham Radio Switzerland
Karin Ueber
Postfach 2454
D-7850 Loerrach
West Germany

Ham Radio England
c/o R S G B
Alma House
Cranborne Road
Potters Bar
Herts EN6 3JW
England

APRIL 1987 / $2.50

ham radio

magazine

hr

focus
on
communications
technology

ham radio

magazine

APRIL 1987

volume 20, number 4

ham radio *magazine* is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00; three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service): one year, $37.00
All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 116

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents

220 AT RISK— ACT NOW

comments close April 6.

REFLECTIONS

novice enhancement and the 220 MHz band:

the FCC giveth...

Novices are back on phone — for the first time since the 1960s — as this issue of *ham radio* arrives in your mailbox. In its Report and Order of Novice Enhancement (effective March 21, 1987), the FCC expanded the Novice 10-meter allocation to 28.5 MHz and awarded new VHF/UHF allocations at 1-1/4 meters and 23 centimeters. Phone operation is now permitted on all three bands.

In brief, on 10 meters Novices (and Techs, who share Novice low band privileges) may now use digital (F1B) as well as CW from 28.1 to 28.3 MHz, plus CW and SSB from 28.3 to 28.5 MHz. The power limit remains 200 watts. On 1-1/4 meters, they're authorized all modes from 222.1 to 223.91 MHz, with a 25-watt power limit. On 23 centimeters, the Novice band is 1270-1295 MHz (all modes), but with only 5 watts.

There's one important limitation: while Novices will be permitted to *use* repeaters, they won't be permitted to be repeater control operators or trustees. Note: contrary to a widely circulated but erroneous interpretation of the new rules, Novices' signals may be repeated outside the Novice subbands, just as Techs' signals can be repeated on 10-meter cross-linked repeaters or through the satellites. This means that Novices will be able to communicate directly with higher class Amateurs on the other VHF/UHF bands through cross-linked repeaters.

They'll have to pass a more difficult exam, however. Instead of 20 questions, they'll face 30 — with the additional ten testing knowledge relevant to the new privileges.

So what's this going to mean for Amateur Radio? First, it means there are now 80,000+ Amateurs with phone and digital privileges on 10 meters and first-time access to all modes on VHF and UHF. Despite the diminished sunspot cycle activity, 10-meter operations should see a big boost. At its worst, 10 generally shows some life — and greatly increased activity on a "dead" band often confirms that its not really dead, but only lacking users! One-and-a-quarter meters should benefit at least as much as 10 — with equipment costs and performance about the same as 2 meters, and a well-established repeater system in place, this band could even become as busy as 2 meters! One unknown is just how well the newcomers will be received; the message is mixed on this, with some repeater groups already planning cross-band links to further expand Novice horizons, while others vow they'll install elaborate coding systems to keep Novices off their machines — or even shut their repeaters down entirely.

Twenty-three centimeters will also see some increase in activity, with good quality commercial equipment available from several suppliers. However, costs are high and activity low, so the effects here are not likely to be nearly as extensive.

What new Novice privileges will mean to the Amateur Radio service is yet to be determined. Though enhancement doesn't make the Novice a no-code entry-level license, it does radically augment its benefits by the addition of phone privileges. If this results in a big boost in newcomers, it may temper enthusiasm for a code-free license — perhaps the perceived problem with the Novice license hasn't been its requirement for 5 wpm code capability, but rather that its only former benefit was to permit the holder to work CW (and CW is *work* when you're new at it).

One thing enhancement seems sure to do is increase activity among present Novices, and that's good for Amateur Radio. The dropout level for Novices has always been unacceptably high, but the new phone privileges should substantially change that. Why? Because Novices will find both their investment (in new equipment) and return on that investment (fun) increasing to the point where they'll not only be unwilling to let their licenses expire, but will be stimulated to upgrade. All things considered, then, enhancement appears to be a big plus for Amateur Radio.

Before we become too euphoric, however, let's consider this:

...and the FCC taketh away!

Excitement over Novice enhancement was still growing — in fact, the news was still being spread — when the FCC dropped the other shoe . . . squarely on 220 MHz. **In a Notice of Proposed Rule Making dated just two days after the Report and Order on Novice Enhancement, the Commission proposed reallocating 220-222 MHz to land mobile service use only!**

As justification, the FCC cites "light loading" of the band in comparison to 2 meters, using ARRL's Repeater Directory listings as evidence. Even assuming this "evidence" is accurate (which it isn't, since the 220-MHz band supports many control links and a large, dynamic, and growing number of packet and other data communication users who've come to 220 MHz because 2 meters couldn't accomodate them), it's obvious the Commission's right hand doesn't know what its left is doing! You don't give 80,000 new users access to a finite band of frequencies, then cut that band by 40 percent! It's worth noting, at this point, that this proposal *did not* come from the FCC's Personal Radio Bureau, where Amateur Radio and our problems are well known and appreciated, but from the Office of Engineering and Technology, where they obviously aren't!

That's not to say this proposal wouldn't have made better sense 10 years ago. In fact, back then it might have even been to our advantage. Why? Because, along with taking 220-222 MHz away from Amateurs, the FCC is also proposing removing fixed and mobile service allocations from the 222-225 MHz segment and making that portion solely Amateur (though shared

(continued on page 50)

comments

a question of goals

Dear HR:

When we read about the [ARRL] Board's approval in principle of a new Amateur Radio museum ("It Seems to Us," *QST*, October, 1986), we thought it was a nice idea.

Then we read an editorial by Craig Clark, N1ACH, in *ham radio* ("Reflections," October, 1986) and kicked ourselves for not thinking about this issue more carefully.

Craig pointed out, we think correctly, that the project will consume enormous amounts of time, energy, and money. In light of the Board's ambitious goals, set in 1984, to recruit new hams and ARRL members, it just doesn't make sense to divert our focus to an equally ambitious undertaking — one that probably will not increase the number of new licensees significantly.

We're all for keeping HQ and W1AW in good shape, but how many of us get a chance to visit Newington? Will a museum in Connecticut inspire non-hams across the nation to get a license? Wouldn't it be better to raise and spend $2.7 million on recruiting new hams?

For that kind of money we could buy, stock, staff and operate several mobile displays which could present ham radio exhibitions and give license exams at schools, museums, fairs, clubs, and shopping centers throughout the country. Let's take Amateur Radio to the people instead of expecting them to come to us.

We urge all League members to read Craig's editorial and convey their feelings to their Division Directors immediately. This important issue should be thoroughly debated by the membership.

Dick Green, KA1LBW, and Mike McAmis, WA3ECT
Etna, New Hampshire 03750

low-band operation

Dear HR:

K2RR's articles in the May and June issues ["Secrets of Successful Low-Band Operation," pages 16 and 17, respectively] prompt me to dash off a few lines on that subject.

Let me preface my remarks by setting the time frame and locations for my experiences on 80 and 40 meters. In the years 1956 through 1966, I was fortunate to operate from three locations in Europe and two in North Africa.

I will do my best to recall a few of the QSOs and without reference to the old log books, which are not now at hand.

October, 1958 saw me in North Africa on 40 meters (though on a few occasions, I did get down on 80 meters). One memorable QSO was with the late Jim Mills, ZL2BE. Jim ran several big rhombics, and knew that I could "borrow" some even bigger ones from the military. Well, to make a long story short, we had a QSO or two, using long path, short path, and probing the other paths as well. Hams at both ends of the circuit were somewhat amazed to hear us on what they considered a dead band. Needless to say, I have fond memories of QSOs like that, so many years ago. No one is more pleased than me to see the tremendous strides that have been made in the design of antennas and equipment in recent years.

Now, let me jump ahead to the 1960s and recount a few experiences on 80 meters. On 80, most any evening, I would be working other Europeans. We, of course, were in darkness, but the east coast of the U.S. was still in daylight. As the evening wore on, out of the noise would come the signal of, say, W1FRR (now W1FC). Fred would say, "Hey, Warren, I've been calling you for an hour now. Didn't you hear me?"
My retort: "No, Freddie, not a peep until just now."

One-way skip? Perhaps so, but how do you explain it? Was my signal going to the "F" layer, bouncing off the Atlantic in mid-path, then traveling in the "E" layer and then down to Fred? Theory has it that since my "E" layer had dissipated, and Fred's had not, the early evening path employed both "F" and "E" layer from east to west, or dark to daylight.

Now, let's see what we can do to explain the bending, or azimuthal divergence of radio signals. With the advent of large, directive arrays on the ham bands, Amateurs are experiencing what the commercial stations knew decades ago. Let me give you an example: a commercial point-to-point station in Slough, England, ran daily traffic with a similar station in Capetown, South Africa. The path between them was normally North-South, as you would expect. But on some occasions, both stations would have to slew their antenna arrays to a point off South America. I don't recall when this situation was first observed, nor do I remember when I read about it, but suffice it to say that it was not in recent times. By the way, this effect has occurred on numerous occasions over the past several years.

How do you explain this bending thing? Well, far more knowledgable persons than I have explained it this way: bending can take place when the layer is spherically stratified. What makes this bending different from backscatter or side-scatter is that the signal is not diluted or fragmented, as it may be in a scattered signal.

I have many other thoughts on low-band DXing, but will save those for another time.

Kudos on your fine magazine and the folks who make it all happen.

Warren Lufkin, W0SII
Cheyenne, Wyoming 82001

real coax:
impedance and phase relationships

The device between the transmitter and antenna deserves better treatment

K2BT, author of the definitive series on phased verticals[1], examines in his own precise manner the extremely important and often neglected component that gets your signal from here to there. — Ed.

We all know that when using coaxial cable at radio frequencies, it may have a significant loss which must be considered. It's quite clear that a cable having a loss of 3 dB/100 feet at 30 MHz will deliver only half the available power to the antenna if we need to use 100 feet. But how many of us are aware that there's a further loss if the load is mismatched to the line? Or that a lossy coax can make a badly matched antenna look good in the shack? In fact, it's possible for a quite low-loss cable, if long enough, to indicate a 1:1 SWR at its input even though the output is open-circuited! And though coax losses at lower frequencies ordinarily can be neglected, as the SWR goes much above 5:1 we still can sustain a non-trivial loss and a different input impedance than we might have expected due to the high mismatch. (Incidentally, additional loss due to load mismatch can occur with any lossy circuit, not just coax.)

Those of you who've seen graphs of additional loss attributable to SWR may have wondered, as I did, just how this loss was calculated. These effects may be appreciated in a general way, but we might be hard pressed to attach numbers to some of these situations. The mathematical formulations dealing with this subject, strewn with Greek letters and unfamiliar trigonometric symbols, give the appearance of such formidability that we are dissuaded from looking any further. And so we often approach the problem "assuming the lossless case...", knowing this is not reality but hoping we haven't missed it by much.

The purpose of this article is to help with such assessments and to place some of the calculations into a simplified and standardized format for ease of programming computers and calculators.

common approach: interpolation

Trying to assign loss at a given frequency when the ratings are given at other frequencies is the first problem we encounter. Most cable manufacturers publish loss figures at various frequencies — for example: 1, 10, 50, 100 MHz and so on, which are called attenuation constants and defined as the loss in decibels per 100 feet with a matched load. But if the operating frequency is 21 MHz, what now? We can "eyeball" interpolate, but it turns out we can do it to a high degree of precision using the manufacturer's ratings.

definitions

Before proceeding, we must come to some general understanding:

1. A transmission line is a uniform system consisting of two parallel conductors. "Uniform" means that the materials and geometry of the line and its surrounding medium remain constant throughout the length of the line. This applies whether the line is parallel wire, coaxial, stripline, or other configuration. This understanding about uniformity also applies to the electrical circuit coefficients that result from the materials chosen for this line.

2. The currents in the line conductors flow only in the direction of the line. It may seem redundant to state this in discussing distributed circuit transmission lines. However, under certain conditions some or all of the current may propagate around the conductors

Forrest Gehrke, K2BT, 75 Crestview Road, Mountain Lakes, New Jersey 07046

instead of along them. Such transmissions are known as "waveguide modes" and are not explainable by distributed circuit theory. For lines with conductor separations that do not exceed a few inches, these waveguide modes are not supported except at frequencies in the very high GHz range. However, although these modes do not propagate any appreciable distance at the frequencies we are interested in, they are excited by any discontinuities in the line, whether caused by too sharp twists or bends or abrupt physical terminations of the line. These excitations die out quickly from their point of origin, traveling a distance no greater than a few times the conductor separation of the line. However, they are responsible for anomalous behavior that occurs in the vicinity of such discontinuities.

For now, so that "discontinuities" are not simply read as being only characteristic impedance variations, it should be clearly understood these are *physical* discontinuities. For example, the junction of an RG-8 line with an RG-174 line (two lines with the same characteristic impedance but very different physical dimensions) is such a discontinuity.

3. The frequency range of interest is generally 1 MHz to 1 GHz, a range more than sufficient for most Amateur Radio interest. Although coaxial transmission lines are used above and below this range, the equations presented in this article must be used with more knowledge about certain specific characteristics of the line. For example, as the frequency is reduced below 2 MHz, the characteristic impedance of the coax will have an increasingly significant reactive component. This may not be a show-stopper, but including that component in calculations will improve accuracy. As frequency is progressively lowered (less than 100 kHz), not only will we see a more reactive characteristic impedance, but the resistive component will rise — slowly at first — and then more rapidly. As we go above 1 GHz, losses at some point may rise disproportionately and unpredictably because of various problems such as insufficient braid coverage in flexible line allowing power loss by radiation. Waveguide mode anomalies — for example, those due to distortions caused by having been bent around too small a radius — also become more troublesome at these frequencies because the excited modes are operating over what are now larger fractions of wavelengths.

4. All discussion and equations assume steady-state conditions and no active elements.

ABCD network parameters

In a previous article discussing design of drive networks for phased vertical arrays,[1] I presented material on the ABCD network matrix parameters. ABCD matrix algebra was devised for the purpose of simplifying calculations of input/output impedances, current, and voltage for four-terminal networks and for facilitating cascaded calculations when chaining networks. The parameters are defined in such a manner that whether a passive network is a length of coax, a Pi or T circuit, or anything else, so long as the parameters are identical — regardless of the differences in individual components or hookup — the input/output relationships are unchanged at the frequency for which the parameters are identical. For the purposes of the referenced article, I felt the subject of dealing with real coax to be an undue digression even though definitely related, particularly for phased arrays at higher frequencies, or even at lower frequencies when driving an element through an excessively mismatched line. Indeed, it is to fill in that gap that this article was written.

For the lossless case, the ABCD matrix parameters for a length of coax are:

$$\begin{array}{c} A \\ C \end{array} \begin{bmatrix} \cos\theta & j\,Zo\sin\theta \\ j(\sin\theta)/Zo & \cos\theta \end{bmatrix} \begin{array}{c} B \\ D \end{array}$$

θ = Electrical length (degrees or radians)
Zo = Characteristic impedance

In order to account for loss, these parameters must be defined differently. We arrive at them and can go back to the lossless case simply by substituting zero for the loss terms.

$$\begin{array}{c} A \\ C \end{array} \begin{bmatrix} \cosh\Gamma\ell & Zo\sinh\Gamma\ell \\ (\sinh\Gamma\ell)/Zo & \cosh\Gamma\ell \end{bmatrix} \begin{array}{c} B \\ D \end{array}$$

Γ = $(\alpha + j\beta)$ Propagation constant
ℓ = Physical length
Zo = Characteristic impedance

At first glance this matrix looks much the same, but there are important differences: the familiar circular functions (sin, cos) are replaced with hyperbolic functions (sinh, cosh), and a term called the "propagation constant" appears for the angle. The propagation constant combines loss and length in the form of complex numbers.

propagation constant

Engineers refer to many of the coefficients involving transmission lines as "constants," a term not well chosen considering the inconstancy of some of them as frequency is changed. The propagation constant consists of two coefficients, the real term α, called the attenuation factor, and the complex imaginary term β, the phase factor. Both are unit factors — that is, they refer to a value per unit length. The calculation for any particular section of line implies a specific length; if the terms of the propagation constant are multiplied by the length in consistent units, whether length is in meters or feet will not matter because the result is total loss and total angle for that length of line. Angular units may be degrees or radians, consistent with the trigonometric functions being used, but the unit of loss must be in nepers.

attenuation factor α

American coaxial cable manufacturers typically use the decibel as the *unit of attenuation*, usually rating a cable in terms of decibel loss per 100 feet. We'll need to convert these loss figures into nepers. Both the neper and the decibel are logarithmic functions of the ratio of power flowing at two points in a circuit. Their mathematical definitions are:

$$Decibel = 10 \log_{10} (P1/P2) \tag{1A}$$

$$Neper = 0.5 \log_{\epsilon} (P1/P2) \tag{1B}$$

The decibel is based on decimal logarithms while the neper uses the natural or Naperian base, 2.71828••• which is usually written as ϵ. Appropriately, neper is a Latinized spelling of Napier, in honor of the Scottish mathematician who invented logarithms. The neper is by far the larger unit; for example, a 2:1 ratio of power is expressed as 3.0 decibels but only 0.35 neper. More precise conversion factors are:

1 neper = 8.686 decibels
1 decibel = 0.1151 neper

Even the decibel is usually too large to be used "per foot" for coax. Consequently, attenuation is quoted in decibels per 100 feet.

Rated loss figures for transmission lines are given in large MHz intervals (1, 10, 50, 100, and so on), which brings us back to the question of an accurate interpolation method for frequencies between them. We can produce an empirical interpolation by taking advantage of the known loss versus frequency characteristics of cable materials. Over the frequency range of interest there are two major loss contributions: loss in the conductors and loss in the dielectric material. We can say then that the total loss is equal to these two components:

$$\alpha_T = \alpha_C + \alpha_D \tag{2}$$

From various references we learn that the loss of round copper wire due to skin effect varies as the square root of the frequency. For any given cable this can be stated as:

$$\alpha_C = m \sqrt{f} \tag{3}$$

where *m* is a constant for any given cable type.
The dielectric loss is found to vary directly with frequency:

$$\alpha_D = nf \tag{4}$$

where *n* is a constant for a given cable depending on the insulation used, its thickness, and so on.
For a first approximation and to the degree that the constants *m* and *n* remain independent of frequency:

$$\alpha_T = m \sqrt{f} + nf \tag{5}$$

Using the rated loss α_{T1} and α_{T2} at two frequencies f_1 and f_2 for any given cable and these identities for the loss components, two simultaneous equations can be written. Substituting and solving for *m* in one equation and then back-substituting to solve for *n* we get:

$$m = \frac{\alpha_{T1} \cdot f2 - \alpha_{T2} \cdot f1}{f2 \cdot \sqrt{f1} - f1 \cdot \sqrt{f2}} \tag{6}$$

and

$$n = \frac{\alpha_{T2} - m \cdot \sqrt{f1}}{f1} \tag{7}$$

Let's test this interpolation method with a real example where we know in advance the result we should expect:
Amphenol rated RG-58/A coax:
0.44 dB/100 feet loss at 1.0 MHz
1.4 dB/100 feet loss at 10.0 MHz
3.3 dB/100 feet loss at 50.0 MHz
Using the loss values for 1.0 MHz and 50.0 MHz and solving for the two constants *m* and *n* in **eqns. 6** and **7** specific to RG-58/A coax between these frequencies:
$m = 0.435604$ and $n = 0.004396$
Let's see how well we can predict the manufacturer's rating at 10 MHz using these constants in **eqn. 5**:
$\alpha_T = 0.435604 \cdot \sqrt{10} + 0.004396 \cdot 10 = 1.42$ dB loss/100 ft.
The manufacturer gave his ratings to two-digit accuracy; we can say we came tolerably close. This interpolation method is quite accurate over the span of frequencies 1 MHz to 1 GHz when using a 10:1 range of rated frequencies. For many applications, even larger ranges are acceptable, as the 50:1 ratio of this example shows. A word of caution: the constants for *m* and *n* shown above apply only to RG-58/A. Don't try to use the same values for *m* and *n* with another cable type unless the loss ratings are identical.

phase factor β

Technically the phase factor is defined in angular units per unit length, radians per meter in the MKS system. Multiplying this value by the total line length would give us the angular electrical length. Since frequency modifies this factor, a value independent of frequency has been found more useful. Furthermore, just as with attenuation, our concern is the line total. This more practical ratio is the velocity factor, *vf*, usually given as a decimal fraction or a percentage.[2] For our purpose it obviates the need to know β, but gives us the means to derive it if required. Velocity factor is a ratio of the propagation speed of electromagnetic waves through the line as compared to its speed in a vacuum. This latter velocity is the same as the speed of light, designated *c*, and is equal to 299.8×10^6 meters (983.5×10^6 feet) per second. If we divide either of these values by frequency in Hz,

we obtain the free space full wavelength, respectively, in meters or feet. Multiplying this length by the velocity factor of the line, one obtains the full-wave *electrical* length. Since there are 360 degrees or 2 π radians in a full wave, we can also state this length in angular units.

A source of much confusion to many Amateurs — all the more confusing when electronics professionals sometimes thoughtlessly equate them — is the difference between angular electrical length and angular current or voltage phase change. Not helping matters are the descriptive terms used — for example, "delay line," referring to a phasing line, with "delay" implying a time-related factor. There are applications in which a propagation time delay is truly meant (radar, for instance), but usually we mean relative phase change, which is *not* time related. (If it were, we'd never be able to advance it!) On the other hand, electrical length *always* refers to time; it is determined by the time required for a particular frequency wave to travel through a medium. For any line, *phase difference* can be varied by changing the termination impedance, but propagation time is invariant, being related only to the velocity of electromagnetic waves in the medium.

As we have seen, propagation time can be defined in several ways, all referring to velocity. The most obvious, time itself, is not easily measured directly. The more commonly used measuring sticks are wavelength and angle. Frequency, velocity, and time are directly and unchangeably related for any medium; when a piece of transmission line is said to be a quarter-wavelength long, this means the propagation time is 1/4 of the time required to travel a complete wavelength at a particular frequency. Since frequency is involved and there are 360 degrees in a complete wave cycle, we can also state it as the number of degrees represented by the time interval. But never confuse this angular representation of propagation time with the current or voltage phase angle difference that may exist between the input and output of this line; they have quite different meanings. It's true that if we match a line with its characteristic impedance, its angular electrical length will be the same as the phase difference, but keep in mind how that coincidence is brought about. Antenna elements seldom meet that requirement without help; your chances of a coincidence is little better than your chance of being hit by a meteor.

Phase change is the angular difference in the voltage or current cycle measured between two points in a circuit under steady-state conditions. Furthermore, in most instances we are concerned with *relative*, not absolute phase change. Note the word "circuit"; phase change may occur in any circuit and can be made positive as well as negative in certain circuits.

An apt analogy for explaining the difference between angular phase change and angular propagation time is the count of the number of cars of a train between two markers along a railway. At the steady-state condition (a continuous line of cars between markers) only car length, not the speed of the train, would influence the count. Conversely, the time required for a particular car to pass by both markers — the propagation time — owes nothing to the count of cars between markers, only to velocity.

If propagation time has nothing to do with phase difference, then why so carefully measure the length of these "delay" lines? This stems from a need for a specific current or voltage phase difference. In my railway analogy, suppose a particular car count is wanted between markers. If the length per unit (degree, radian, or railroad car) can be controlled, then the total count can be predetermined. If 90 degrees is the phase difference desired and the termination impedance is made a pure *resistance*, then a quarter-wave line — that is, a 90-degree line, will produce the required phase change. The impedance qualification is absolutely essential, because the nature of the termination predetermines, or controls, the phase change. If the load isn't a pure resistance, the phase change won't be 90 degrees and all the care going into measuring the length of this line will be as useful as rearranging the deck chairs on the Titanic. For emphasis, let's put this another way: it's entirely possible, with certain termination impedances, for a 70-degree electrical length line to have a 90-degree phase difference in current.

solving complex hyperbolic functions

There are two approaches to solving complex hyperbolic functions: expansion of the complex hyperbolic function into functions of real circular and real hyperbolic angles, and direct evaluation of the complex exponents of ϵ. The first method is useful where real hyperbolic functions are available in calculators or computer programs or from textbook tables.

Expansion method.

$$\cosh(\alpha + j\beta)\ell = \cosh \alpha\ell \cdot \cos \beta\ell + j \sinh \alpha\ell \cdot \sin \beta\ell \quad \textbf{(8)}$$

$$\sinh(\alpha + j\beta)\ell = \sinh \alpha\ell \cdot \cos \beta\ell + j \cosh \alpha\ell \cdot \sin \beta\ell \quad \textbf{(9)}$$

These relationships expand the complex hyperbolic functions into functions of real circular and real hyperbolic angles. For every term in the expansion, including the j terms, the real function values may now be substituted. Compared to direct evaluation, which follows, this method offers simplicity of calculation, provided real hyperbolic function values are available. (You C language aficionados finally may have found a use for your hyperbolic functions, which are a standard component of most C compiler math libraries.)

From these expansions, we can get the terms for the lossless case for coax calculations. If α is zero, then the real hyperbolic sines equal zero and the hyperbolic cosines equal one resulting in:

$$\cosh(\alpha + j\beta)\ell = \cos\beta\ell \qquad (10)$$

$$\sinh(\alpha + j\beta)\ell = j\sin\beta\ell \qquad (11)$$

This means that the lossless case need not be provided as a separate calculation in a program. If the loss is entered as zero, a program using hyperbolic functions will carry out the calculations correctly. The angular units for these calculations had best be radians. Besides, published tables and computer functions for real hyperbolics always use radians for angular units. Loss must be in nepers.

Direct evaluation. For most of us the method using complex exponents of ϵ (the Naperian base 2.71828•••) offers the better solution because it requires access only to real circular functions:

$$\cosh(\alpha + j\beta)\ell = \frac{\epsilon^{(\alpha + j\beta)\ell} + \epsilon^{-(\alpha + j\beta)\ell}}{2} \qquad (12)$$

and

$$\sinh(\alpha + j\beta)\ell = \frac{\epsilon^{(\alpha + j\beta)\ell} - \epsilon^{-(\alpha + j\beta)\ell}}{2} \qquad (13)$$

It can be shown that:

$$\epsilon^{\alpha\ell} \bullet \epsilon^{j\beta\ell} = \epsilon^{\alpha\ell} \bullet (\cos\beta\ell + j\sin\beta\ell) \qquad (14)$$

and

$$\frac{1}{(\epsilon^{\alpha\ell} \bullet \epsilon^{j\beta\ell})} = \frac{1}{[\epsilon^{\alpha\ell} \bullet (\cos\beta\ell + j\sin\beta\ell)]} \qquad (15)$$

Note that eqns. **14** and **15** are the rectangular equivalent of the polar vector representation:

$$\epsilon^{\alpha\ell} \underline{/\beta\ell}$$

and

$$\epsilon^{-\alpha\ell} \underline{/-\beta\ell}$$

Either **eqns. 14** and **15** or **eqns. 16** and **17** may be used. Since many scientific calculators have polar/rectangular conversions, eqns. **16** and **17** would be a good choice. The problem is now reduced to one that can be handled by calculators or computers with real circular functions (phase may be in degrees if this suits the purpose). Loss must still be in nepers.

At **line 140** of the complex hyperbolic functions, note the statement **S** = 10^(S/20). This is the decibel-to-neper conversion. It avoids the use of the irrational number ϵ. Instead, it is stated as a fractional exponent of 10. Because this equality may not be immediately obvious, here is its explanation:
As stated previously:

$$\text{dB} = 0.1151 \text{ neper} = \log_{\epsilon} \sqrt{P1/P2}$$

$$\text{or } \epsilon^{0.1151\text{ dB}} = \sqrt{P1/P2}$$

$$\text{and dB} = 10 \log_{10} P1/P2$$

$$\text{or } 10^{\frac{\text{dB}}{10}} = \sqrt{P1/P2}$$

Taking the square root of both sides of this equation:

$$10^{\frac{\text{dB}}{20}} = \sqrt{P1/P2}$$

therefore

$$10^{\frac{\text{dB}}{20}} = \epsilon^{0.1151\text{ dB}}$$

Put it down to the fact I don't like having to remember and type irrational numbers or odd fractional conversion factors. (Another of my favorites is PI = 4• ATN (1). Let the computer remember PI, and to as many places as it can muster!)

example explains

I've always found that when learning a new calculation procedure, nothing breeds confidence like being able to duplicate the results of a step-by-step example calculation. I've therefore chosen an example which highlights some of the surprising things that can happen with real coax and a high mismatch.

The frequency is 14 MHz, using RG-58/A 50-ohm coax. The load is 10 - j10. The electrical length is 2 wavelengths (4π radians or 720 degrees); since the velocity factor is 0.66, the physical length is 92.74 feet. The load current will be assumed to be 1 + j0 amperes. Using the interpolation equations and the rated loss at 10 and 50 MHz, the loss at 14 MHz is 1.67 dB/100 ft. For our line length, the loss is 1.55 dB or 0.178 neper.

COSH (0.178 + j4•π) = 1.0159 + j 0
SINH (0.178 + j4•π) = 0.1794 + j 0
The ABCD matrix parameters:
A = 1.0159 + j0
B = 8.9612 + j0
C = 0.0035 + j0
D = 1.0159 + j0
Network calculations:
AZ_L + B = 19.1206 − j 10.1593
CZ_L + D = 1.0517 − j 0.0358

Z_{IN} = (AZ_L + B)/(CZ_L + D) = 18.490 − j 9.029
E_{IN} = I_L•(AZ_L + B) = 21.652 $\underline{/-27.983\text{ (degrees)}}$
I_{IN} = I_L•(CZ_L + D) = 1.052 $\underline{/-1.952\text{ (degrees)}}$

VSWR at load: 5.2:1
VSWR at input: 2.8:1
Total power into coax: 20.47 watts
Power dissipated in load: 10.00 watts
Total loss: −3.11 dB 10.47 watts
Normal loss: −1.55 dB 4.28 watts
SWR loss: −1.56 dB 6.19 watts
Efficiency: 48.8 percent

The first thing to notice is how this relatively small loss of 1.55 dB has given the VSWR as measured at the input of the line an optimistic look. The high

Simple BASIC program calculates complex hyperbolic functions

Using the polar form for calculating the complex hyperbolic functions requires surprisingly few BASIC statements. It may be instructive to list these, which can be set up as subroutines to be called by the subroutines which are calculating the ABCD matrix values.

```
100 'Sinh  S=dB total loss, T=total radians; s+jt returned.
110 FL = 1: GOTO 140
120 'Cosh  S=dB total loss, T=total radians; s+jt returned.
130 FL = 0
140 S = 10^(S/20): GOSUB 170: S3 = S: T3 = T: GOSUB 190
150 IF FL = 1 THEN S = (S3 - S) / 2: T = (T3 - T) / 2: RETURN
160 S = (S3 + S) / 2: T = (T3 + T) / 2: RETURN
170 'Polar to rectangular; S=Mag.,T=Angle (rad.); s+jt returned.
180 S2 = S: S= S2 * COS (T): T = S2 * SIN (T): RETURN
190 'Invert 1/(s+jt);  s+jt returned.
200 U = 1: V = 0
210 'Divide (u+jt)/(s+jt);  s+jt returned
220 Y = (S * S) + (T * T): S = S / Y: T = T / Y
230 'Multiply (u+jt)*(s+jt);  s+jt returned
240 W0 = (S * U) - (T * V): T = (S * V) + (T * U): S = W0: RETURN
```

Comments prior to each subroutine indicate the operation performed, parameters to be passed, and parameters returned. All calculations are complex. Some of these routines are general purpose functions: polar-to-rectangular conversion, inversion, division, and multiplication.

Adding square root and rectangular-to-polar subroutines would complete a minimum set for handling the majority of complex algebra calculations. Though not necessary to the calculations in this article, they follow here:

```
300 'Square root. S=Real,T=j Term; s+jt returned.
310 'If S returned as 0, issue warning. J term may be minus or plus.
320 W0 = SQR ((S + SQR (S * S + T * T)) / 2)
330 IF W0=0 THEN T= -SQR (ABS (S)):S=0:PRINT "Sign OK j term?": RETURN
340 T = T / (2 * W0): S = W0 : RETURN
350 '
360 'Rect.to Polar. S=Real,T=j Term. S=Magnitude,T=Radians returned
370 PI = 4 * ATN (1)
380 Y = SQR (S * S + T * T): IF S = 0 THEN 450
390 W0 = ATN (T / S)
400 IF S > 0 THEN 440 ELSE IF T > 0 THEN 430 ELSE IF T = 0 THEN 420
410 T = W0 - PI: GOTO 480
420 T = PI: GOTO 480
430 T = W0 + PI: GOTO 480
440 T = W0: GOTO 480
450 IF T < 0 THEN 470 ELSE IF T = 0 THEN 480
460 T = PI / 2: GOTO 480
470 T = -PI / 2
480 S = Y: RETURN
```

To preserve accuracy, keep calculations in rectangular form as far as practical; avoid multiple polar/rectangular conversions except as necessary at input or output of data. By convention the variables *S* and *U* are real, while *T* and *V* are the j terms. (In polar/rectangular conversions, *S* is magnitude and *T* is the angle.) The returned variables are always *S* and *T*.

VSWR at the load has caused an additional loss of 1.56 dB. And even though this line is a multiple of a half-wave, where we'd normally expect to see the load impedance repeated at its input, it is in fact quite different.

I must emphasize that these effects result from line loss. If we could magically produce a lossless line, none of these effects would be seen, no matter how high the VSWR. For all that, had I chosen a much lower loss line, these effects would be drastically reduced. Reflected wave power, which would not be lost in a lossless line, gets a piece taken out during each traverse of the line — just as with forward wave power. This is the reason for the additional loss due to the high VSWR.

summary

Real coax, except in the most benign circumstances (good load match, very low loss), gives rise to effects which can be startlingly different from assumptions based on a lossless line. Nor is it entirely a problem of efficiency and optimistic VSWR. A case in point is the 4-Square vertical phased array, whose reference element requires a small part of the total drive power (on the order of 5 percent). Because of the high VSWR associated with the feedline of this element, the assumption of zero losses (even at 80 meters) results in a non-trivial error in the calculated input impedance of this feeder, leading to a drive current phase error. Since good f/b ratio is a vector subtraction of large numbers looking for a zero sum, a small error can lead to a large f/b ratio change.

ABCD matrix algebra again demonstrates its versatility and flexibility for four-terminal network calculations. Except for adding complex hyperbolic functions to my computer program, and coax loss interpolation, no other changes were necessary. Given the parameters, it doesn't matter to the ABCD program what sort of network it is calculating.

acknowledgments

My thanks again to Mason Logan, K4MT, and Bob Booth, WB6SXV, for their encouragement and assistance. They pointed the way; I wrote about it. A special thanks to Bob, who provided the interpolation method.

references

1. Forrest Gehrke, K2BT, "Vertical Phased Arrays, Part 5," *ham radio*, December, 1983.

2. Some cable ratings give the dielectric constant of the insulating material — e.g., polyethylene has a dielectric constant of 2.26, which equates to a velocity factor, $vf = 1/\sqrt{2.26} = 0.67$.

bibliography

Radio Engineers' Handbook, F.E. Terman, McGraw-Hill, pages 19 and 178.
Transmission Lines, Robert Chapman, Schaum Outline Series in Engineering, McGraw-Hill.

ham radio

simple modifications and adjustments for the TS-930S

Minor changes let you align without test equipment, improve performance and reliability

The Kenwood TS-930S offers the serious Radio Amateur the opportunity to enjoy the high quality of an all solid-state, general coverage transceiver with a very effective built-in automatic antenna tuner, among a number of options. Furthermore, Kenwood's updated version, the TS-940S, provides all the same features plus improved cooling, increased memories, and keyboard data entry. For those using the TS-930S — and to some extent, those using the TS-940S — the following notes may be of interest.

memory backup

The TS-930S memory backup requires the use of three 1.5-volt AA batteries, which will easily last their shelf life. AA NiCads, however, may be substituted with good results; because the drain is only in the microampere region, recharging will be required only about once a year. This can be done by simply attaching some small clip-type probes to the polarity coded red and black leads that exit the battery housing on its left side (as viewed from the top, front of the radio).

i-f alignment

The rather laborious i-f alignment procedure outlined in the factory service manual may be greatly simplified by using the receiver's 100 kHz marker as a signal generator in conjunction with the S-meter. For convenience, and as a reference, the receiver's internal "S9" meter adjustment is used to set the marker level to S9. This provides relatively accurate signal readings, consistent with those I would give by ear. Unfortunately, the incoming signals above that level will read high, but in reality those are only relative at best, and I prefer the convenience of accuracy below that point, where it's more useful. Some operators may prefer a setting of S8 as a compromise, depending on their particular needs.

The service manual's instructions for the alignment of L132 and L134 in the rf processor i-fs are quite complex. To simplify this procedure, you can use your voice as a signal generator while peaking the slugs as indicated on the *compression* scale of the radio's multimeter. Alternatively, a complex sound such as fan noise picked up by the microphone and detected in the monitor mode will suffice by just peaking the audio signal without the meter reading.

dial calibration

To align the TS-930's 10-MHz time base for basic dial calibration, the following procedure will provide a simple, yet very effective means of relatively accurate calibration. First, tune WWV to the highest frequency in which an S9 or stronger signal can be copied. With the receiver in the *a-m* mode, enable the 100 kHz marker and adjust the rf attenuator until the optimum beat note is heard in the form of the conventional "whooshing" sound, while adjusting TC1 for zero beat. The best results will be obtained when the two signals are of equal amplitude — i.e., when the strongest beat note is heard. Always perform this calibration when WWV is well above S9 to allow for the maximum adjustment range of the rf attenuator.

preventing failure in R400

In all TS-930S units with serial numbers below 4,100,000,* resistor R400 on the signal board is prone to failure. In my radio, the precursors of failure were

*There are obviously not 4.1 million TS-930Ss — the manufacturer's numbering system simply identifies products in this manner. Ed.

Marv Gonsior, W6FR, 418 El Adobe Place, Fullerton, California 92635

suggested by a VOX malfunction and a 15-minute delay in the ALC meter reaching zero. Several other 930 owners have told me that they've found R400 in their units discolored and too hot to touch; this strongly suggests a high probability of failure.

The measured power dissipated in this resistor is 1/2 watt with a 1.5-k value. The original rated dissipation of this resistor was either 1/4 or 1/2 watt (the reason for this uncertainty is that my failed resistor wasn't returned to me, and the manufacturer doesn't specify resistors in their parts lists). As originally designed, it was the only hot resistor on the signal board. In all models numbered above 4,100,000, Kenwood changed its value to 2 watts, so be sure to inspect this resistor for discoloration and measure its value. The existing resistor may be replaced by crushing its body and soldering the new one to the remaining leads; if you do it this way, you'll have to remove the signal board. Of course, if you're removing the board any way, you might as well replace the resistor.

R400 is difficult to find because it's not located in the area of its sequential grouping, but instead at the top left center of the signal board, as viewed from the bottom side of the radio (facing you). If you have the service manual — a bargain at $15, by the way — you can find R400 at the intersection of C and 1.5.

ALC considerations

Some operators have been experimenting with the ALC time constants, with the objective of increasing the 930's "talk" power. They believe that some minor improvement may be accomplished by decreasing the decay time of the ALC, since this varies by the net tolerances of the components involved. However, any alteration (delay) of the *attack* time should be avoided because doing so will only increase the intermodulation distortion products. A senior Kenwood factory engineer has advised that any ALC indication *above zero* causes an increase in distortion; therefore, ALC should be used sparingly and in accordance with the operating instruction manual. Should the decay time be found to be excessive (that is, about 5 seconds from half scale), it may be reduced by changing R240 — located at the intersection of 4 and C/D (see page 39 of the service manual) — on the signal board to a smaller value. Unfortunately, unless you remove the board, you'll have to crush it, salvaging its leads for the replacement.

rf decoupling

Like most solid-state equipment, the TS-930S exhibits some degree of rf susceptibility, even under very low VSWR conditions. Coil cords make excellent antennas. So do any other cables to external units such as speakers, phone patches, and keyers. The liberal use of ferrites, consistent with good shielding practices, will usually take care of most problems. It's axiomatic that all external leads should be decoupled.

Evidence of external rf entering the radio and resulting in distortion may be found as follows. Wearing headphones, turn off the monitor and determine whether a garbled SSB signal is heard. Next, place the multimeter in the Vc position and note if it remains well regulated under full power conditions, especially with a power amplifier in operation. Poor Vc regulation is a sure indication of a problem, either because of rf or in the regulator circuit itself.

improving transmitted audio, greater IMD suppression

Users of radios with serial numbers below 3,080,001 may not be aware that a Kenwood factory modification was inaugurated at that point for improved transmitted audio quality — i.e. improved IMD suppression. The modification consisted of increasing the collector current of the rf drivers and final transistors, the MRF485s and the MRF422s in their quiescent state. The effect is more pronounced in the reduction of the higher, odd order products. The full details can be found in Kenwood's Factory Service Bulletin No. 867 (March 29, 1983), entitled "TS-930S SSB TX Tone Quality." The enhanced performance occurs by operating the drivers and finals deeper in Class AB1, by increasing their collector idling currents from 50 and 500 to 70 and 1100 mA, respectively. To determine if this mod has already been incorporated in your radio, place the multimeter in the Ic position and compare the value you read to the 1100 mA. To some extent, the results of this mod account for the difference in transmit quality between the earlier and later versions of the 930.

Thanks to W4CG, a 5-dB improvement in the IMD of the radio may be readily obtained by replacing Q1, the rf pre-driver (a 2SC2075) with a Motorola MRF485. It's essential that the MRF485 be of current manufacture because early devices exhibited a thermal runaway problem which has since been corrected by Motorola. The new, improved version is identified by a narrow white horizontal stripe across the face, just above the device identification number. The MRF485 is an ultralinear device, especially designed for SSB service and therefore just a bit better in this application than the 2SC2075, while being fully interchangeable in form, fit, and function. Therefore, no parameter change is required. Replacing the device is actually quite simple. It can be a bit of a chore in the 930 because of the tedium of removing the rf board from its mounting; in the 940, the job is much easier.

quieting a noisy cooling fan

In most radios, the power supply fan will become

noisy after a year or two, depending upon the particular fan unit and the number of hours of use. Kenwood has developed a simple modification that greatly reduces or eliminates it. The mod consists of adding a small spring clip (Part No. 602-0549-04) to laterally load the fan shaft. Described in Kenwood's Service Bulletin No 893, the mod takes only about 30 minutes.

I've also found that a light Teflon™-loaded lubricating oil such as Tri-Flow™ is an excellent lubricant for the front bearing of both fans. However, unfortunately, neither fan is designed for lubrication of the rear bearings.

increasing dial light life

In order to save the multimeter dial lights, which are costly and based on a special pigtail design, Kenwood recommends that they normally be operated in the "dim" position. However, a 12-volt Radio Shack unit (No. 272-1141, 79¢) can be substituted and wired in series for the 28-volt source.

ergonometric "face-lifting"

Adding some 1-inch rubber extensions to the front mounting feet will make viewing the controls easier, thereby helping the operator's posture and possibly lessening eye strain. (This will be especially true for contest operators.) These rubber extensions are obtainable at parts supply houses or hardware stores at a nominal cost. I cemented mine to the existing feet with 5-minute epoxy.

balanced modulator stability

I've observed a *frequent, random* imbalance between the capacitative and resistive balance adjustments. While the radio undoubtedly meets its carrier suppression spec, it is rather disconcerting to observe the imbalance occurring. Therefore, it's a good idea to check the balance periodically, using another receiver as a detector or an oscilloscope with a dummy load across the output of the radio. While the amount of carrier may be small, it may become quite annoying when it's amplified by a linear and a beam. When using an auxiliary receiver as the detector, advance the Processor In control fully clockwise and reduce the Processor Out control counterclockwise to the fully off position. This provides the best combination for checking without audio feedback.

conclusion

All of the foregoing procedures may be accomplished without test equipment and without following the detailed factory instructions, yet they should yield the same results. I hope that these methods and observations will, in some ways, add to your operating pleasure while using these fine radios.

ham radio

packet radio conference bridge

AX.25-compatible bridge links six stations for routine or emergency communications

From the beginning, packet radio has been essentially a point-to-point mode. Even with the TNC-2's multi-connect capabilities, it hasn't been possible for all participants in roundtable or net-type operations to be connected to everyone else in the net. Although makeshift arrangements have been devised, they've lacked the anti-collision and error-controlling capabilities of the AX.25 protocol.

In an effort to solve these problems, Tom Aschenbrenner, WB5PUC, has designed a truly error-controllable, AX.25-compatible conference bridge. Because it's combined with other network software components he's designed, the conference bridge is offered in two versions. The one described here fits into a replacement EPROM for a TNC-2 clone; the other is a part of the software installed in the 9600-baud network node controller board for TexNet.[1,2]

A conference bridge module in a TNC-2 clone or a TexNet node provides full-protocol, multiple-station roundtable or net-type operation between packet stations. Typical operation is accomplished by each of the stations involved in the net connecting to the bridge-equipped node by using the Secondary Station Identifier (SSID) assigned to the conference bridge function. On the test nodes in operation in the Dallas area, the SSIDs are -2 and -3 on each node. The current version of the network software supports two independent conference bridges of six participants each. It's also possible to connect to the bridge through one digipeater if necessary.

typical conference bridge operation

To connect to a conference bridge, each station connects as if it were connecting to any other packet station. A typical text sequence to a conference bridge would be:

C WB5PUC-2 <carriage return>

The operator's TNC does the connect routines.

The following will then appear on the operator's CRT:

*****Connected to WB5PUC-2 <cr lf>**
(from TNC)
Welcome to the WB5PUC Conference Bridge. A Control-U shows all stations connected to this bridge.

At this point or at any other time, the response to a Control-U command to the bridge will bring up a text string listing the calls of all connected stations. For example:

N5EG-5 WD5HJP W5YR-7 WA5MWD-3 connected

No additional commands are needed to operate the bridge.

In the normal operation mode, each operator receives a text string with a shorter header indicating the call of the originating station. For example:

WD5HJP> Transmitter power is now at 100 watts.
N5EG-5> OK Bill, try adjusting trimmer C15 now.
W5YR-7> What are you guys up to?
WD5HJP> Hi George, just adjusting the node's final amp.

When the QSO is over, those connected to the bridge simply disconnect as they would from any other packet connection, via a DISCONNECT command in the Command mode of the TNC.

operations test

A routine test of the emergency plan for the Point Beach, Wisconsin nuclear power plant in September, 1986, provided an intensive on-the-air test of an early version of the conference bridge software. Though not specifically designed for such use, the conference

Bill Wade, WD5HJP, Texas Packet Radio Society, 600 Via Sevilla, Mesquite, Texas 75150

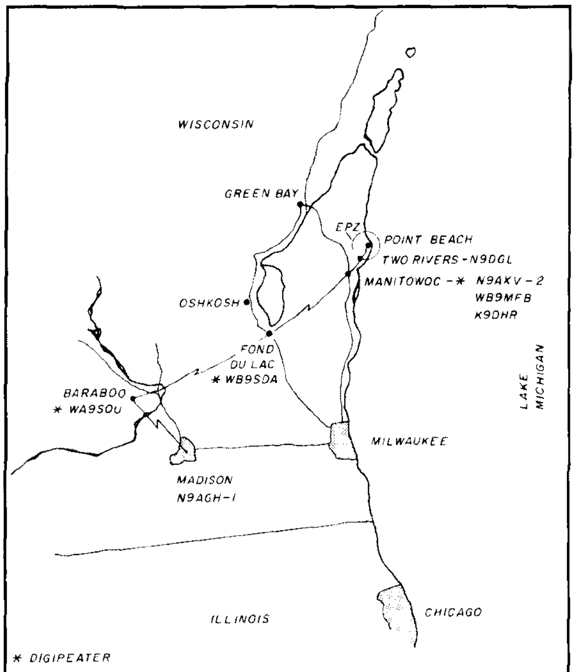


fig. 1. Conference bridge linked six stations in nuclear plant emergency exercise.

bridge served as the hub of an emergency communications network that included a link to the state capital. Overall, the bridge performed well in its original form; later modifications have been implemented to facilitate its use in emergencies.

The Nuclear Regulatory Commission (NRC) requires annual testing of every nuclear power plant's emergency plan. This test is designed to evaluate the ability of plant personnel and the utility company holding the facility's license to cope with an accident. The NRC measures their ability to assess the extent of danger to the public, their effectiveness in recovering control of the plant, and their ability to minimize damage to the surrounding environment. A succession of events pushes the plant engineering staff through a series of critical decisions; events are programmed into the scenario to simulate damage to the power plant and motivate recovery action by the staff.

For a realistic overview of the performance of the allied agencies that would be involved in an actual incident, the test scenario includes a simulated evacuation. State, county, and municipal emergency units become involved in the plan when supervisory NRC engineers and the utility's power plant engineers have recognized a possible threat to public safety. At some point in the escalation of the situation, the plant staff recommends evacuation, triggering activation of a number of government safety, information, and public assistance centers.

At that point, the power plant staff contacts the county and state emergency units and delivers its assessment of the situation. The complement of offices that become active in the evacuation phase of the emergency plan are the county Emergency Operations Center (EOC); the state Emergency Government Office (EGO); the Department of Human Resources Reception Centers that will process evacuees; the Joint Information Press Center (JIPC), the official information center for the emergency; and the off-site power plant Emergency Operations Facility (EOF), from which the NRC and utility supervisory engineers make their recommendations to the state and county emergency government.

Each of the 102 nuclear power plants in operation in the United States is surrrounded by an Emergency Protection Zone (EPZ) with a radius of 10 miles. This EPZ is the area considered under immediate hazard in case of any airborne release of radioactivity. The Point Beach power plant EPZ includes three towns — Two Rivers, Shoto, and Two Creeks — and extends into Lake Michigan.

test scenario

This particular scenario began with a hypothetical earthquake tremor, causing a series of leaks in the cooling loops of the "B" power plant. Subsequent "damage" to the plant caused some injuries and contamination of plant employees and allowed the release of radioactive steam into the atmosphere. By 8 AM, after a damage assessment, the county and state government were notified that there was a "public danger"; the county emergency office notified the Manitowoc RACES EC, who activated the amateur emergency system. Stations equipped with 2-meter fm voice and packet equipment were established at each of the operations centers listed above, with the exception of the plant Emergency Operations Facility (EOF), not normally accessible to the public.

RACES participation

The Amateur community in Manitowoc County is actively involved with the county emergency government office. During the test, the five-station RACES system was centered around the Manitowoc County EOC, which has a permanent Amateur Radio station linked via microwave to a dedicated voice repeater (WB9MFB, 145.19/.79) located at the county transmitter facility. Four remotely-sited, linked voting receivers increase the effectiveness of this 60-mile diameter service area, 2-meter fm voice system. For packet operations, a permanent conference bridge-equipped packet digipeater (N9AXV-2, 145.01 MHz) utilizing an MFJ-1270 TNC-2 is installed at the transmitter site. The voice repeater and packet digipeater are converted 100-watt Motorola transceivers.

Other equipment used at all of the temporary public service Amateur stations included additional 2-meter fm voice transceivers for the RACES 145.19/.79 repeater. Voice fm was used to coordinate large file transfers and to back up the packet equipment. A variety of computers (chiefly IBMs and IBM clones and Commodore 64s) and TNCs (AEA, Kantronics, MFJ, and original TAPR 1's and 2's) were used without any compatibility problems. Each of the locations was equipped with the appropriate disk drives; some were also equipped with printers.

Operators at each of the centers connected to N9AXV-2, the conference bridge/digipeater at the county transmitter site. N9AGH-1 was at the Wisconson State Emergency Government Office in Madison, the state capital. To reach the conference bridge, N9AGH-1 connected through two digipeaters, WA9SOU (in Baraboo) and WB9SDA (in Fond Du Lac), a link length of over 150 miles (see **fig. 2**). WB9MFB, at the county EOC, K9DHR, at the reception center in Manitowoc, and N9DGL, at the JIPC in Two Rivers, were all connected directly to the bridge.

Once the stations were connected, typical operation proceeded as in any other net. Net control was maintained by operators at WB9MFB, the county EOC. Traffic was passed simply by sending the text via packet from each of the sites. Since all stations on the bridge were getting identical copies of text, very little repetition was necessary.

impact of packet operation

The worth of the conference bridge and packet radio was demonstrated immediately. The test emergency was declared from the governor's office in Madison, and the message went out via the two-digipeater link to the conference bridge at the Manitowoc EOC. A parallel 75-meter phone system running from the state emergency office to the county EOC was also activated. The packet conference bridge delivered the message correctly, approximately 30 seconds ahead of the 75-meter phone link. The 75-meter system garbled the power plant emergency protection zone (EPZ) grid coordinates in the first message!

In some respects, use of the packet conference bridge became second nature. To simulate a system failure, Ron Shimek, WB9MFB, the county EC, disconnected power to the conference bridge, forcing the use of point-to-point packet communcation. When they became aware of the system failure, packet operators set up point-to-point links to re-establish communication. Although throughput was slower, point-to-point operation did provide usable information. As a backup, a standby station had been set up to monitor activity and act as recorder for the entire test.

test results

At the conclusion of the exercise, the Emergency Coordinator described the conference bridge as a key ingredient in the success of the test. In his report, he emphasized that federal observers had been impressed not only with the speed and accuracy of traffic handling, but also with the capability for time/date stamping of traffic (using the computer systems' real-time clocks) and for producing hard copy simultaneously at *all* sites.

Because all the stations in the emergency system were connected through the conference bridge, automatic status and warning updates were available at all sites. An NRC inspector mentioned to one of the participating Radio Amateurs that thanks to *ham* activity, he was never out of touch with any of the sites for the duration of the test. The Federal Emergency Management Authority (FEMA) observers indicated that they would encourage further use of packet radio and the conference bridge in future tests. WB9MFB's evaluation of the test suggested a broader role for the RACES group in both forthcoming tests and actual emergencies.

recommendations for future designs

The relatively few operation anomalies that caused some delays on the system were largely attributable to QRM originating outside the limits of the test area. The Manitowoc county transmitter site is about 3 miles from Lake Michigan; there is considerable channel activity from Milwaukee and Chicago to the south and from Michigan across the lake. All of the test activity took place on 145.01 MHz. Typically, there are periods of 10 to 20 minutes when the N9AXV digipeater squelch never closes. Selection of another frequency besides 145.01 MHz for operation would be desirable.

Connection of the conference bridge to a network system is also recommended. In this test, the state emergency government center was by necessity connected through a 145.01-MHz, two-digipeater link. Response time from that part of the system was proportionately slower, but still quite usable. Other situations without such a robust digipeater link would benefit from use of a backbone network system. The conference bridge software does allow connection to any network because of its compatability with AX.25.

WB9MFB has suggested that a system monitor be set up in advance to record all activity during an emergency communications test. Packet operation offers a significant advantage in this regard, in that all text information is easily stored to disk. In this case, the system monitor provided a good backup to the NCS; later, when the EC and RACES group needed to do evaluation of their own, the stored information proved to be useful indeed.

Other recommendations include eliminating BBS activity on frequency during tests or actual emergencies to help avoid channel congestion. Operators from outside the test area occasionally interrupted RACES activity with inquiries about the test and the conference bridge.

implications of conference bridge operation

Amateurs who've handled traffic in hurricanes, tornados, or other disasters know that telephone systems are the first communications systems to become overloaded or destroyed. The Point Beach scenario demonstrated that utility companies and state agencies are still blindly tied to this relatively fragile communications resource. The ability of packet radio systems to handle high volumes of traffic quickly and accurately under difficult circumstances is being demonstrated regularly; as part of these systems, a conference bridge can provide reliable communications to the people that need it most.

references

1. Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5SEG, "The TEXNET Packet-Switching Network — Part 1: System Definition and Design," *ham radio*, March 1987, page 29.
2. Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5SEG, "The TEXNET Packet-Switching Network — Part 2: Hardware Design," *ham radio*, April, 1987 page 29.

ham radio

the TEXNET packet-switching network

part 2: hardware design

In last month's article,[1] we discussed network algorithms and the software layering. This month, we'll focus on the design and testing of hardware for the network, and on the results that have been achieved to date.

system partitioning

Partitioning hardware to minimize the number of signals that must connect between units offers three benefits: simplified cabling, easy measuring and modification of individual units, and flexibility in the construction of the network.

Figure 1 is a block diagram of a TEXNET network node. There are four main pieces: a local area network (LAN) radio, which in this case is a 1200-baud AFSK modem and 2-meter radio; an inter-processor (IP) radio (a 9600-baud FSK radio and modem) for use as the high-speed network trunk; a node control processor (NCP) that contains the microprocessor and communications ICs; and the power supply, which contains a three-state float charger, battery, and circuitry for automatic uninterrupted power should ac power fail.

LAN radio and modem

This channel is the primary method by which users with TNCs and 2-meter radios connect to a network node. By connecting the modem separately from the processor, any modem can be used — 300 baud, 1200 baud, 2400 baud, or whatever might be desired. **Figure 2** is a diagram of the modem, which is similar to the TAPR TNC-1 modem. We chose to implement an active filter equalizer with op-amps instead of a switched-capacitor filter IC. The modem includes a 45-second time-out timer to disable the transmitter should the controller fail for some reason. The strap allows setting the EXAR demodulator VCO center frequency, but better results can be obtained by adjusting the VCO frequency control pot and observing the received "eye" pattern on an oscilloscope from an AFSK signal known to be good. An eye pattern is observed on an oscilloscope by synchronizing the scope trigger with the recovered clock and displaying the data. Since the data displayed is not involved in triggering the scope, a random display of all data sequences is shown, but the zero crossings are fixed in time on the screen, yielding an open area in the center of a data bit (known as the "eye"). **Figure 3** shows a typical eye pattern, the recovered clock, and the slicing level (which decides between a 1 and a 0). The basic decision circuit is shown in **fig. 4**.

The radio is an ICOM-IC22S, a popular 2-meter transceiver, with the frequency hard wired to 145.05

Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5EG, Texas Packet Radio Society, P.O. Box 831566, Richardson, Texas 75083-1566

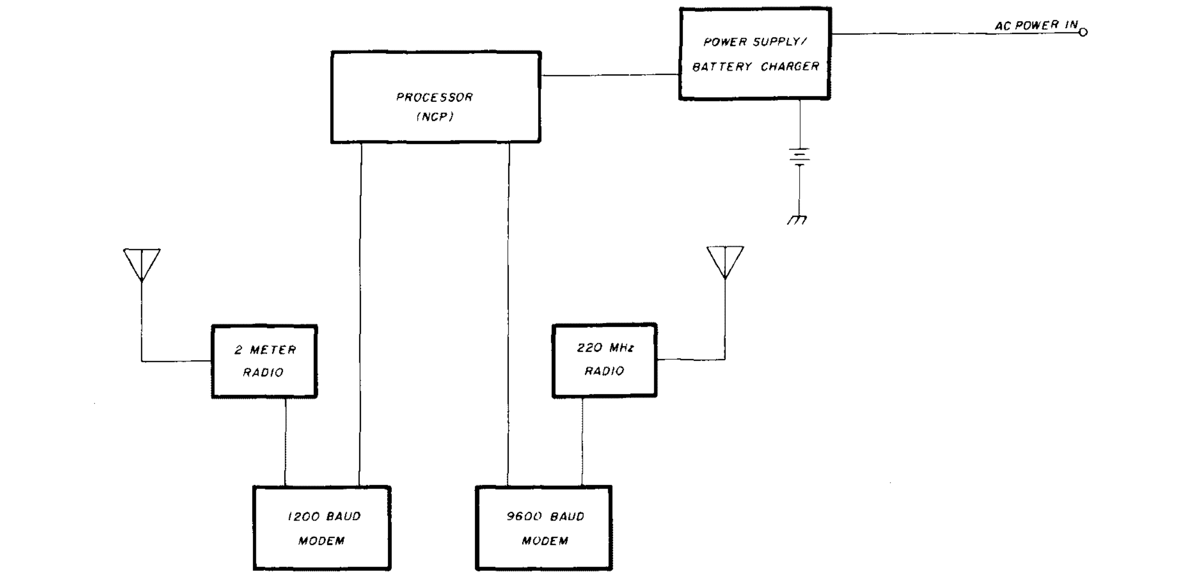


fig. 1. Hardware block diagram of TEXNET node. This diagram shows the partioning of the node into functional blocks, the processor, the two modems / radio interfaces, and the power supply / battery charger.

MHz. The transmit audio is injected after the microphone amplifier; the receive audio is tapped off prior to the audio PA in order to avoid the severe degradation of frequency response that results if the speaker and microphone leads are used for audio pick-off and injection.

IP radio and modem

The performance of the network trunks is very important in determining the overall throughput of the network as a whole. As each user sends traffic into a network node, all traffic is multiplexed (combined) onto the high-speed trunks. Thus the trunks carry a much greater amount of traffic than the user links. Because of this, we have decided to operate the trunks at 9600 baud, with rapid Transmit/Receive (T/R) switching. Rapid T/R switching is required because at 9600 baud, actual packets take relatively little time to transmit, and the T/R delay can determine the effective channel capacity.

Figure 5 illustrates the effective channel capacity versus T/R delay for a 9600-baud channel with no errors, and one acknowledgment packet for the entire transmission. Several different values are shown: one indicates the number of packets per transmission, another the number of bytes per packet, and a third for two values of DWAIT (digipeater waiting time, which allows a digipeater transmission priority). Because there are no digipeaters in TEXNET, DWAIT = 0. (A value of DWAIT = 80 ms is typical for 2-meter channels.) Our experiments involved the use of a pair of Hamtronics FM-5 220-MHz fm transceivers and K9NG's modems. These radios are modified to operate FSK, and the received data signal is tapped off the quadrature detector in the receiver. Since these radios are PIN-diode switched between transmit and receive, we were able to make them operate with 40 ms T/R delay, although in practice 80 ms was allowed.

We encountered some difficulty in making the radios operate properly at 9600 baud. Apparently these problems were due in large part to variations in the performance of different FM-5 radios, which were designed not for high-speed data operation, but rather for fm voice operation. In an effort to improve the operation of the radios, a number of experiments were run, and modifications were made to the modem.

To understand this better, let's review the basics of frequency-shift-keyed (FSK) data transmission, the spectrum of a non-return-to-zero (NRZ) data signal at baseband, and the performance of i-f filters in the time domain. We'll see that all three have to be addressed properly to assure proper performance of the radios and modems.

An NRZ signal is one that toggles between logic 1 and logic 0 no more than once per bit period (see **fig. 6**). In an FSK system, two frequencies are transmitted — one for logic 1, the other for logic 0. At the output of the discriminator/quadrature detector at the receiver, the two frequencies are translated back to voltages. If the frequency of the transmitter were to

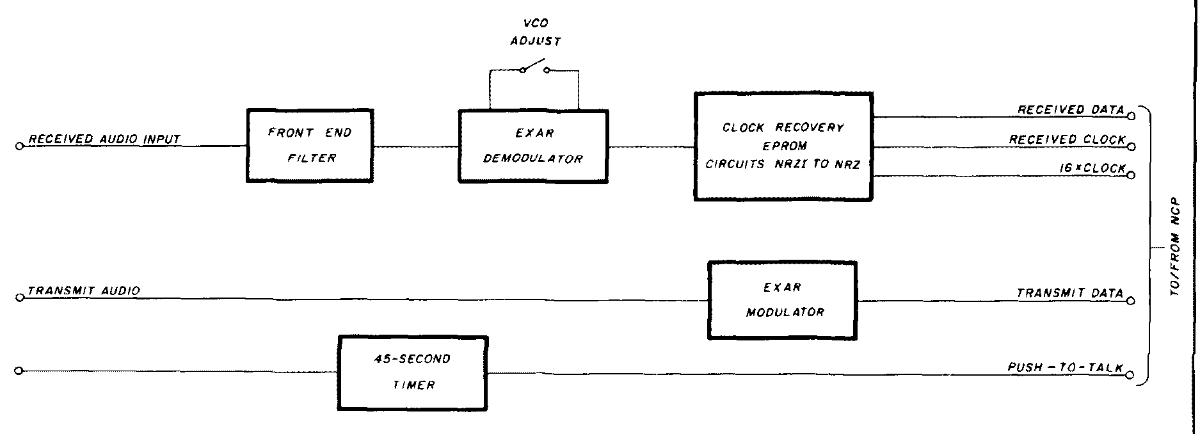
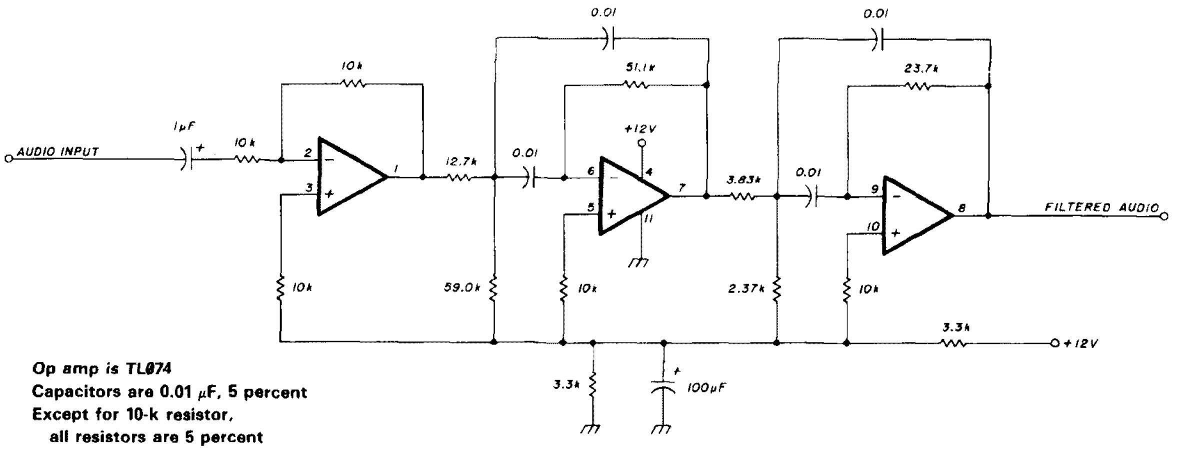


fig. 2A. 1200-baud AFSK modem.



Op amp is TL074
Capacitors are 0.01 µF, 5 percent
Except for 10-k resistor, all resistors are 5 percent

fig. 2B. Front-end active filter schematic.

vary slightly, then both the logic 0 and logic 1 voltages would also vary. A simple method to determine the correct "slicing level" for deciding between a logic 1 and a logic 0 is to choose the voltage halfway between the two. This is simple to do by using a low-pass filter with a time constant quite a bit longer than the data period to generate the slicing voltage level. Then the slicing threshold will "track" the logic 1 and 0 voltages automatically (see **fig. 7**). This requires, however, that the transmitted data have, on the average, the same number of ones as zeros; if they don't, the recovered slicing level will be biased off the true center point (**fig. 7**).

In HDLC, the code used for AX.25, there is no guarantee that the code will be dc-balanced (i.e., have same number of ones as zeros). In fact, the flag character contains two zeros and six ones, thus having a large dc offset from one-half. A simple way to solve the problem is to use a pseudo-random scrambler to cause some apparent randomization of the data sequences. A self-synchronized descrambler is used on the receiving modem to recover the original bit stream. This is the method used on the K9NG modem to send and receive data, a 17-stage scrambler being used. With this arrangement, the average number of ones and zeros is nearly the same. Certain sequences into a scrambler can, however, produce long strings of ones or zeros. If a long string were to occur, our low-pass filter in the receiver would tend to drift off the center voltage, halfway between the 0 and 1. So we must compromise the time constant of the low-pass filter in the receiver slicing level circuit (which we would like to make very long) with the need for rapid T/R switching, where we need to acquire the proper level quickly. In addition, any capacitors used to couple the analog signal must have long time constants; if

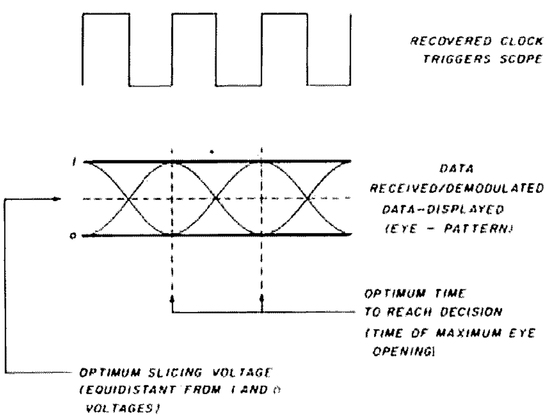


fig. 3. "Eye" pattern, recovered clock, slicing level. This figure shows what an "eye" pattern looks like, and how the oscilloscope is set up to make the measurement. The one/zero decision is made at the slicing voltage level at the instant in time of the rising edge of the recovered clock.

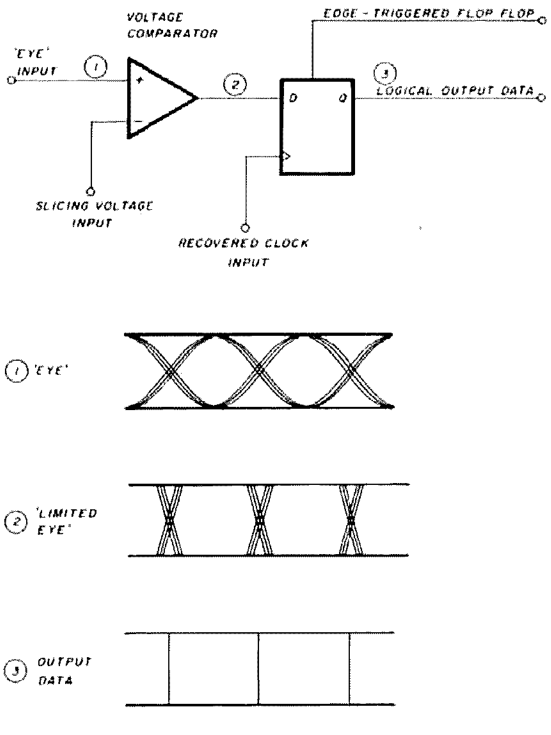


fig. 4. Decision circuit and levels. This diagram shows the decision circuit, basically a comparator and a flip-flop. The timing of the flip-flop clock and the reference voltage into the comparator determine the exact point the decision is reached.

they don't, the average voltage will drift as the low-frequency components from the scrambler charge and discharge the coupling capacitors.

Several modifications of the K9NG modem are associated with increasing the time constant of these circuits, where they're not critical to the T/R switching delay. A list of the modifications is included in **fig. 8.** The most significant improvement came with addition of a group-delay equalizer in the receive section of the modem. In order to appreciate the requirements for this, let's look at how filters work both in the frequency domain and the time domain. A typical i-f filter used in voice or CW work has very sharp "skirts." That is, the amplitude response decreases sharply from the filter center frequency. In addition, the response is relatively flat within the passband. This filter has a great deal of time delay distortion (see **fig. 9**). The time delay is minimum at the filter center frequency and rises sharply at both the upper and lower filter cutoff points. This causes no particular problems with voice, where the distortion of the waveform isn't important. But with wideband data signals, where we need to distinguish the value of data bits that are adjacent in time, the spectral energy nearer to the filter cutoff points will undergo a greater delay through the filter than the energy near to the center frequency. When this signal is converted to baseband (i.e., fm demodulated), it can be shown that frequencies near the fil-

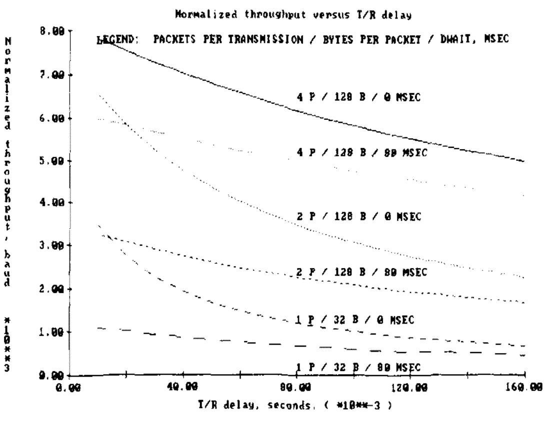


fig. 5. Effective channel capacity vs. T/R delay. This graph shows the effective capacity (baud rate) of a channel for different transmit/receive switching delays, with and without an additional delay, called DWAIT (digipeater wait time). TEXNET does not use digipeaters, so DWAIT = 0.

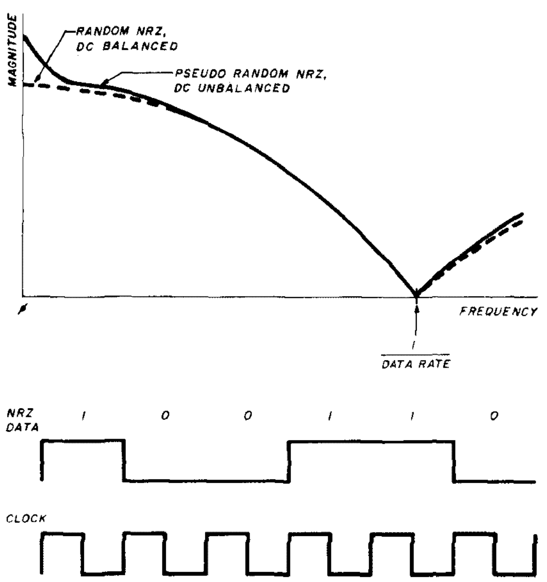


fig. 6. NRZ signal diagram. An NRZ signal has a value of logic zero or logic one for the entire period of the bit. The spectrum of a truly random signal is from dc, diminishing to zero at (1/bit time). A pseudo-random signal has a diminished spectrum near dc, theoretically vanishing.

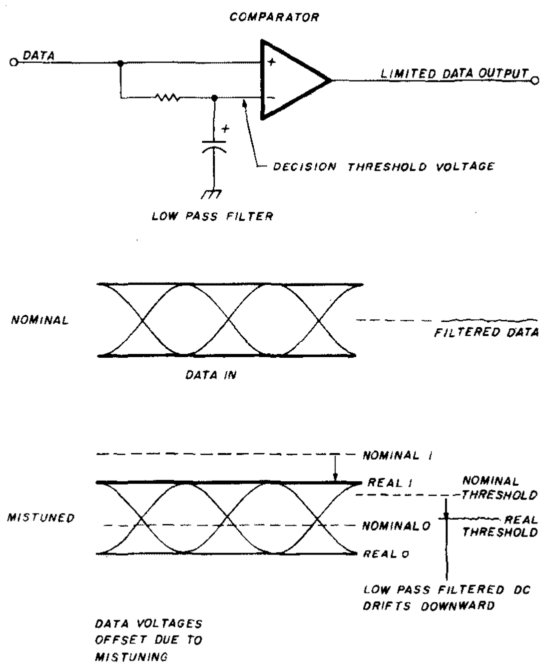


fig. 7. NRZ filtered, slicing level, low-pass filter to generate slicing level vs. frequency drift. If the NRZ is scrambled, so that the code is dc-balanced, then low-pass filtering the data will generate the correct logic-slicing voltage. As the one/zero voltages drift with receiver or transmitter mistuning, the slicing voltage will track automatically.

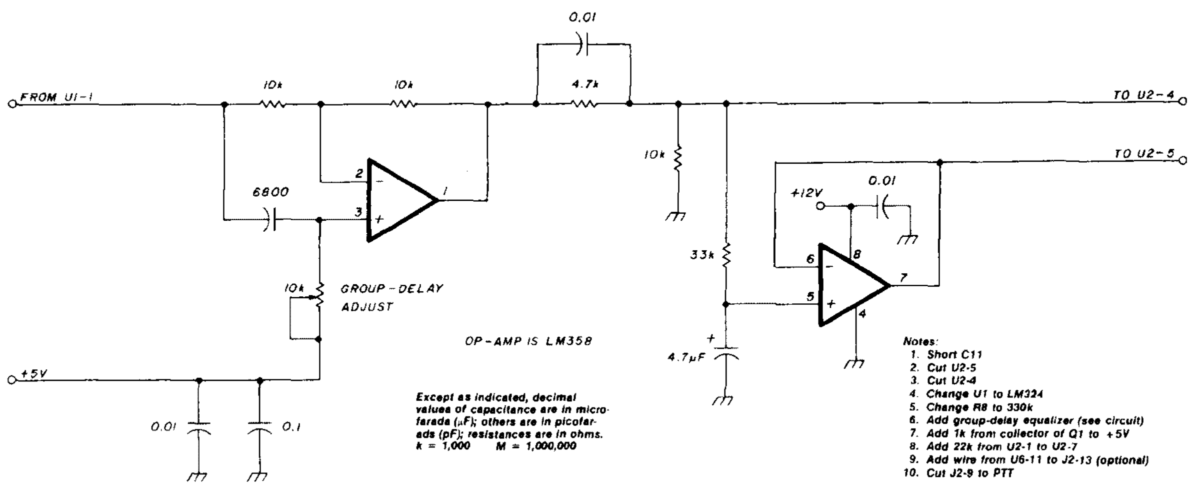


fig. 8. List of modifications to K9NG modem. The reference designators follow the TAPR documentation for the K9NG modem. The list includes all modifications to the modem, and additions (delay equalizer) to the modem circuitry. The schematic shows the additions to the modem.

ter center frequency correspond to the low-frequency spectrum of the NRZ (baseband) signal, while the frequencies near the filter cutoff (away from the filter center) correspond to the higher frequency components of the baseband signal. Thus we can "map" the time delay of the filter into baseband by "folding" the time response about the center frequency, which becomes the zero frequency of the baseband. Thus the filter produces small delay at low baseband frequencies, and larger delay at higher baseband frequencies.

The 455-kHz i-f filter in the FM-5 radio is a sealed ceramic unit; no adjustment is possible. Instead of designing a new filter with desirable time-delay characteristics, we instead built an active filter circuit, with flat amplitude response, but with an adjustable time-delay response. This network has maximum delay at dc, and decreasing delay at higher frequencies. The circuit is adjustable, so that we could construct an approximate inverse time delay to that caused by the i-f filter. **Figure 10** shows the amplitude, phase, and time response of this baseband group-delay equalizer (active filter), and the baseband eye pattern with and without the delay being equalized. After delay equalization, it can be seen that the eye is much more open near the center of the bit, when the 1/0 decision is reached. Our measurements indicated a 7-dB improvement. We also provided about 1 dB of peaking of the frequency response, which opened the eye about 1 dB more, yielding an 8 dB improvement in the receiver. Actual tests with the radios indicated that this made the difference between usable and nonusable performance. Without the equalizer, the radios

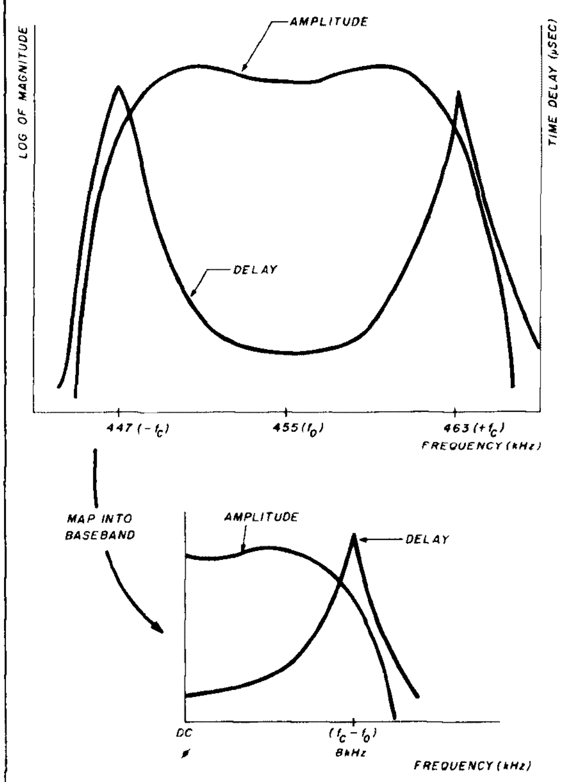


fig. 9. Group delay of 455-kHz i-f filter and map of delay into baseband by folding about F_0. (A) shows the group delay and amplitude vs. frequency for the 455 kHz filter; (B) shows how the band-pass response is mapped into the baseband by "folding" about the center frequency, F_0, of the filter (assuming symmetry in the filter).

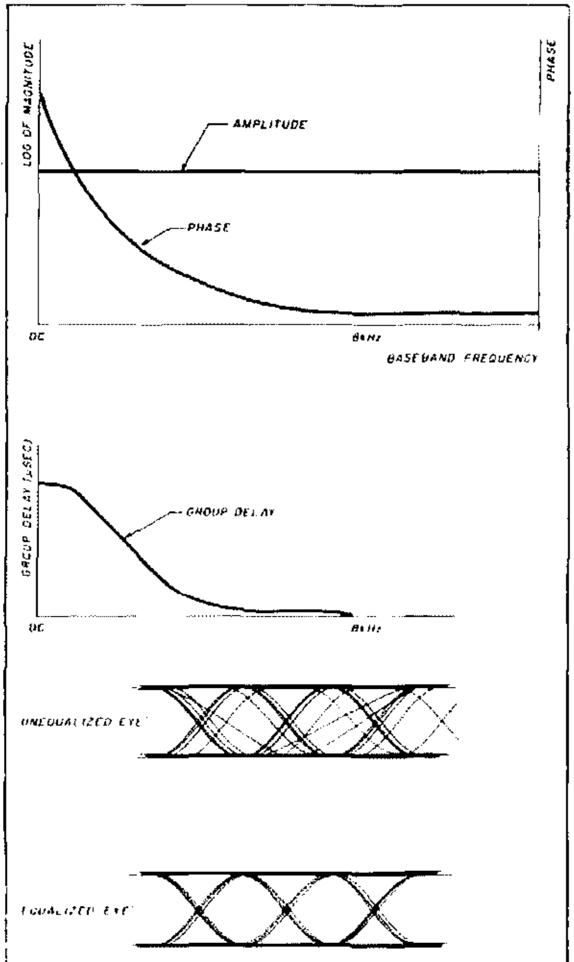


fig. 10. Amplitude, phase, and delay of the group-delay equalizer "eye" with and without equalization. The baseband group-delay equalizer has flat amplitude response, and a varying phase vs. frequency response. The group-delay is the negative of phase slope vs. frequency. Thus the group-delay is large as dc, and diminishes with increasing frequency.

"dribbled" (i.e., had a background error rate regardless of the strength of the received signal), which caused many packets to be lost.

One additional problem that had to be overcome on our "real" path test hop was insufficient image rejection in the FM-5. The test path is in an area where television channels 11 and 13 are very strong. The channel 11 video carrier is near the image frequency of our desired channels (the radio i-f is 10.7 MHz, so the image is 21.4 MHz lower than the signal frequency). **Figure 11** shows a simple filter; **fig. 12** shows its response (S11 and S12). This filter was extremely effective in eliminating the image response.

With these improvements, we've run a 12-mile path on 220.55 MHz at 9600 baud, at better than 98 percent

✓ 180

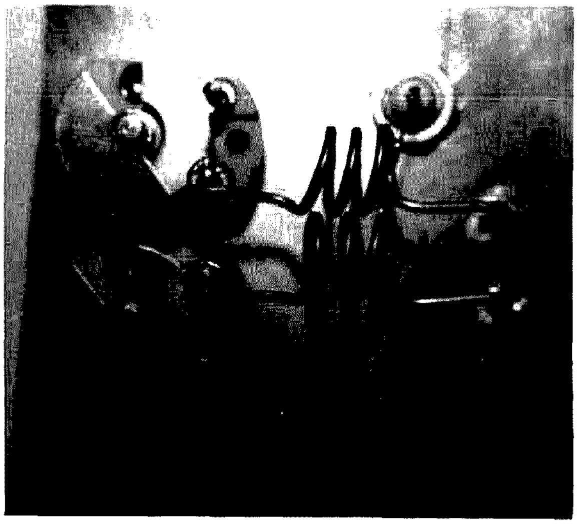


fig. 11. The 220-MHz front-end filter. Air-variable capacitors are necessary for adequate filter Q. The two resonators are closely coupled. The high tap position sets the loaded-Q of the resonators and prevents over-coupling, while maintaining low insertion loss. This filter is exceptionally difficult to tune properly.

reliability — 98 percent of the packets are received without error. This hop is such that 4-dB additional attenuation at one radio caused the packet reliability to be approximately 5 percent, and so was a stringent test of the radios and modems in that the radios were operated near the minimum acceptable received signal level.

The FM-5/K9NG modem experiments gave us valuable insight into proper modem/radio design. We

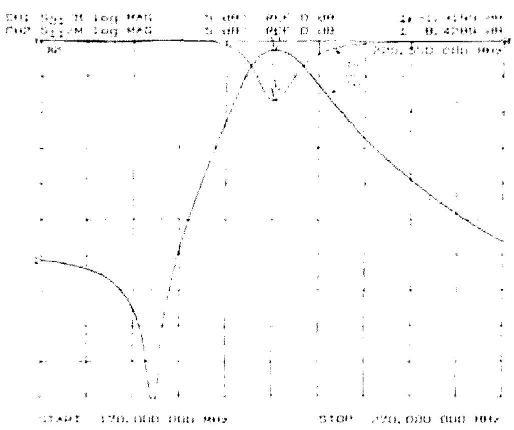


fig. 12. S11 and S12 of the filter. The forward transfer (insertion loss) of the filter is S12, while the return loss (related to input VSWR) is S11. This filter has about 1.3 dB insertion loss, and about 8 dB return loss. The notch is near the image frequency of the 220-MHz receiver.

plan to revise the modem circuits, utilizing surplus commercial 440-MHz equipment for the actual network.

NCP design

The next element in the system is a microprocessor performing as the network switching node. The node control processor (NCP, **figs. 13** and **14**) is an original design, though several modifications have been made since the original artwork was done. The design of the unit is conventional, with a few points emphasized for reliability.

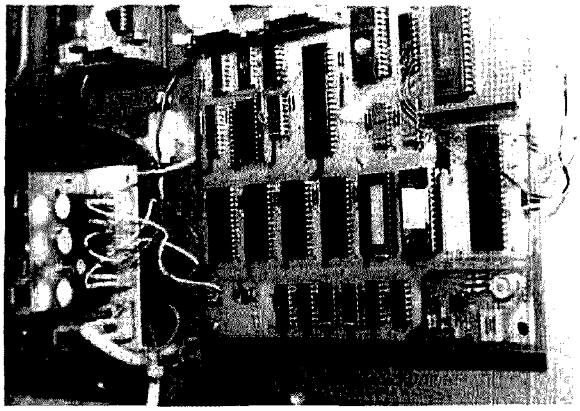


fig. 13. The Node Control Processor (NCP), version 1, with several modifications. A new version 2, which is a multi-channel super-set of the popular TNC-2 unit, is being designed.

The unit contains a Z80 operating at 4 MHz, 32K of EPROM, 32K of RAM, an SIO/2 serial communications IC for the serial HDLC ports, a counter/timer IC (labeled CTC and situated on the modification "ledge" overhanging the main board) for providing the interrupt clock time slices (of 8 ms), and two special circuits. Careful design of the NCP hardware and interrupt daisy chain to match the software was required for the computer to operate reliably at 9600 baud and support multiple HDLC channels simultaneously. All of the I/O devices utilize vectored interrupts through the Z80 interrupt daisy chain. **Figure 15** shows the entire TEXNET node prototype (both radios and modems, ac power supply, and the NCP.

We decided to develop our own board in order to keep costs down and allow the inclusion of two special circuits.

The first circuit is a reliable crystal oscillator. Many logic-gate type of crystal oscillators aren't reliable enough for use in remote, unattended computers. Numerous tests have shown that under certain voltage transients, gate-type oscillators won't start reliably. It's a nuisance to have to climb a tower to recycle the power just to restart a crystal oscillator, and inconvenient to users to have the network out of service during this time. The circuit chosen is a conventional Pierce type, with an additional transistor buffer amplifier. It was tested extensively and found to be robust. (One test to try on an oscillator is to feed the circuit from an adjustable voltage supply. Set the

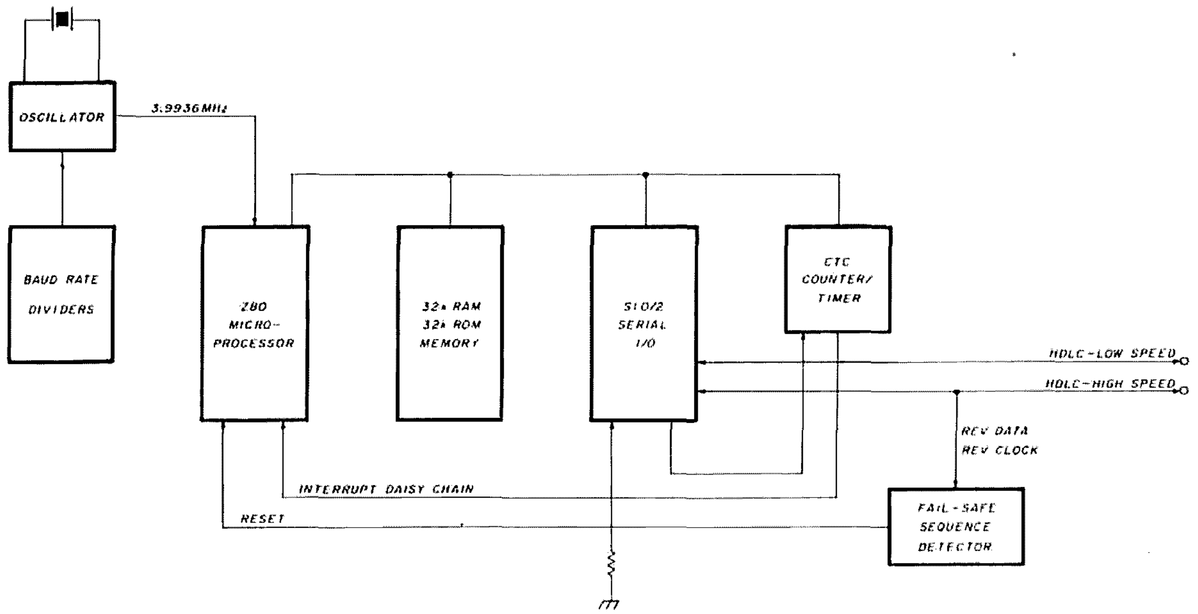


fig. 14. The NCP, showing the crystal oscillator, baud generator, microprocessor, 32 kbytes of EPROM, 32 kbytes of RAM, one HDLC synchronous communication IC, the counter-timer IC, and the fail-safe state machine.

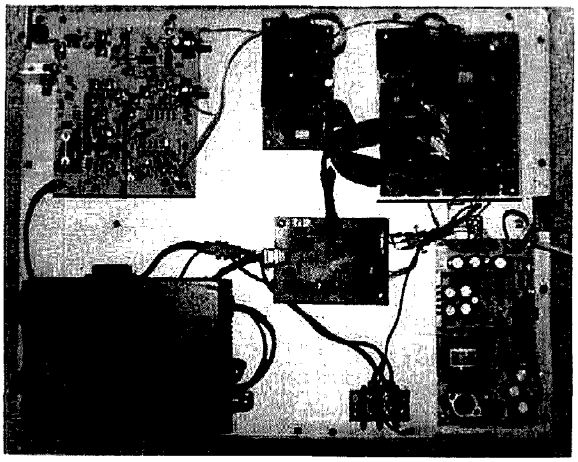


fig. 15. The complete TEXNET node prototype. This is the first prototype of the TEXNET node, which includes the NCP, high-speed modems, the 2-meter radio, the 220-MHz radio, and the ac power supply.

voltage to 0, turn on the power, and very slowly increase the supply potential to the nominal voltage — for example, over a period of 30 seconds. If the oscillator refuses to start, starts on the 3rd harmonic, or starts at the wrong frequency, the circuit should be rejected as unsuitable for unattended operation. Many logic-gate oscillators will fail this test.)

The second special circuit is a fail-safe state machine. This is an EPROM-based logic circuit that monitors the IP data and clock lines (from the high-speed trunk radio), completely independently of the processor or communication ICs. It searches for the presence of a very long (72 bit) sequence. If this sequence is ever detected, the state-machine activates the reset line on the microprocessor, thus restarting the node software. An EPROM contains both the value of the 72-bit sequence and the state-machine code necessary to operate the circuit. Each node is programmed with a different 72-bit sequence, which we've termed the "fire code." Any user of the network can cause the generation of a message with the fire code of a suspected node to be embedded in the message and sent via the network to the suspected node. Thus any node in the network can be rebooted (reset) from any other point within the network. There's a very small chance that ordinary user traffic through the network could resemble the fire code, but since the sequence is so long (72 bits), the mean time between false activation is calculated to be considerably more than 1 million years.

A new version of the NCP will include strappable options, and the circuitry for optional addition of the packet message system (PMS), a 5-megabit hard disk drive-based bulletin board that allows up to ten users to be connected simultaneously. Automatically accessible from anywhere in the network, it's compatible with the W0RLI command set (the most popular packet-radio bulletin board system). **Figure 16** shows the PMS prototype — the world's first turbo-charged TNC-2 clone! This test box contains an ac power supply (vertical), an MFJ-1270 (a TNC-2 clone) with WB5PUC ROM, a disk controller, and a 5-megabit hard drive. The Z80 microprocessor is removed from the TNC-2, and an adapter is plugged in its place. The Z80 plugs into the adapter. The ROM software for both the NCP and the TNC-2 are very similar, except that the NCP supports two radios (or more). The NCP is designed so that it is a superset of the TNC-2 hardware. (Further details will be found Part 3 of this series, which will address software design.)

This concept could be tested as a satellite gateway, perhaps with UOSAT-11, as a store-and-forward message system.

power supply

The power supply for the network node is extremely important in determining the reliability of the network. If the network is to be useful for handling emergency communications, it should be able to survive temporary power outages. Consequently, the TEXNET power supply utilizes a gelled-electrolyte (gel-cel) lead-acid battery, which can provide power for several hours and has a reasonably long life if properly charged and maintained.[3] The power supply for the node utilizes +17 through +24 VDC as the input power source, unregulated (but filtered). The supply/charger (see **fig. 17**) regulates the input to +13.8 VDC through

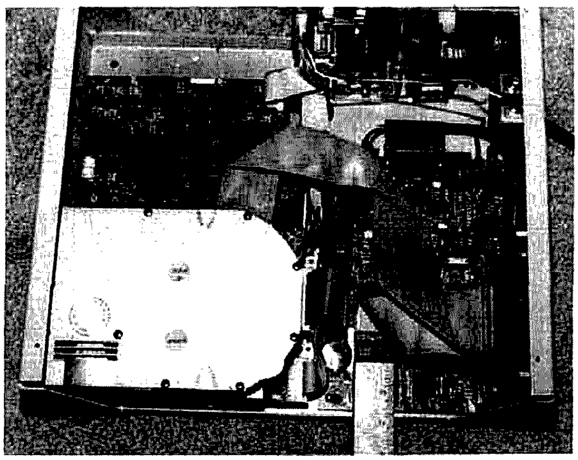


fig. 16. The Packet Message System (PMS), a 5-megabyte hard disk drive-based bulletin board, supports 10 simultaneous users. This prototype includes a TNC-2 clone, the hard drive controller boards, the 5-megabyte hard disk drive, and the ac power supply. A second version is connected to the node prototype, and is accessible from anywhere in the network.

a three-terminal, 10-amp regulator (LM396). The battery charge is controlled by a three-state temperature-compensated charger IC (a Unitrode UC3906). When the ac fails, a relay connects the battery to the load. A capacitor is used to hold up the +5 VDC load voltage for the switching time of the relay. Should the battery completely discharge (i.e., produce less than 12.0 volts dc), the relay protects the battery by disconnecting it from all loads, and the power fails.

The life of a battery is maintained only by very careful charging. This is the reason for the three-state charger. When the battery is initially depleted, it is charged at a constant current of C/10 (at 1/10 the ampere-hour capacity, that's a 10-AH battery charged at a 1-amp current). When the battery voltage rises to nominal voltage (14.25 VDC), a controlled overcharge is initiated. Here the battery is charged at constant voltage (15.00 VDC) until the charge current decreases to C/100 (100 mA for a 10-AH battery). Failure to apply a controlled overcharge will result in the battery's receiving only 80 percent of its previous charge at 14.00 VDC. These voltages are for operation at +25 degrees C aud for gel-cels. Liquid electrolyte batteries require different (i.e., lower) voltages. Variations in temperature require compensation in voltage; if compensation is not made, the battery will be severely undercharged at low temperatures and overcharged at high temperatures. The UC3906 contains most of the circuitry, and a temperature-dependent

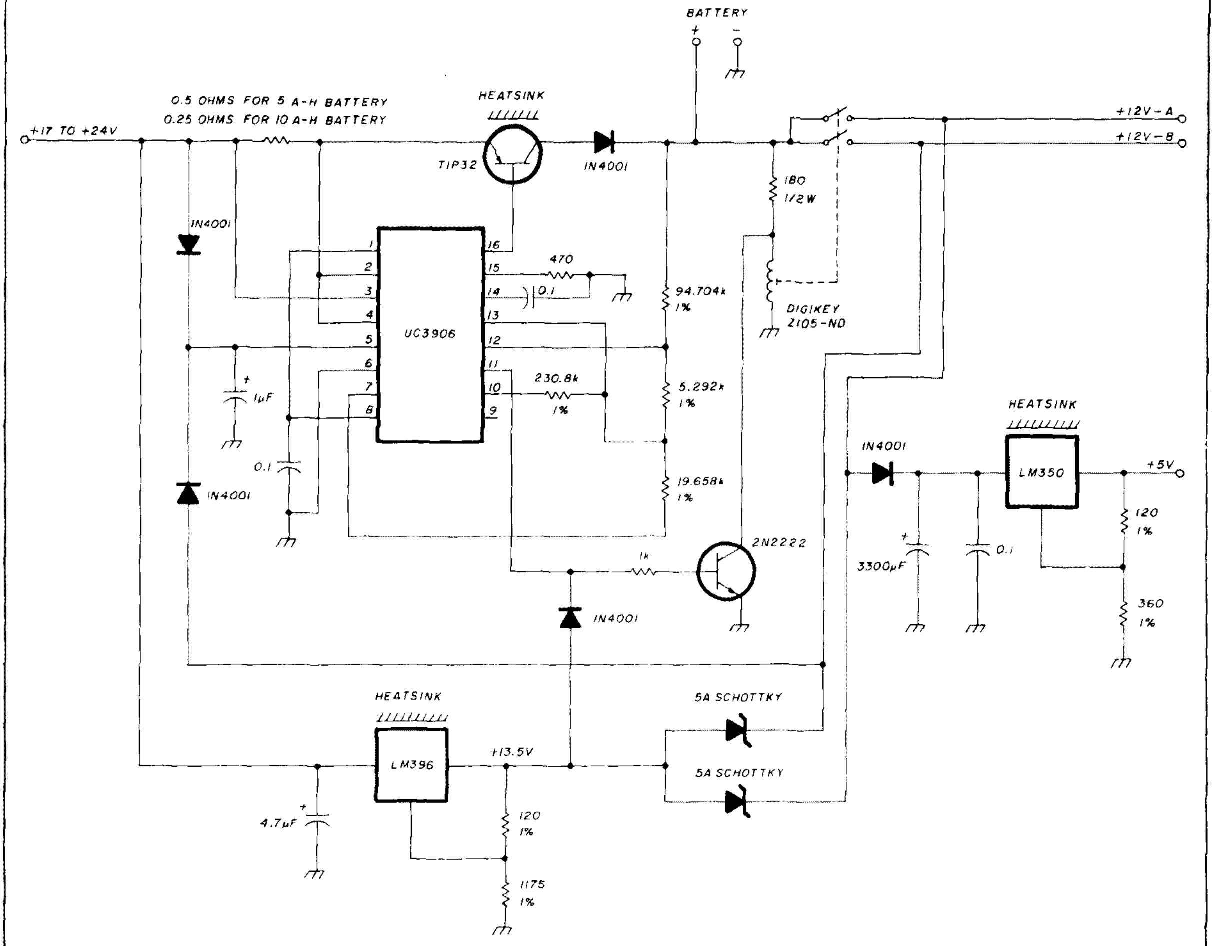


fig. 17. Schematic of battery charger/power supply. The battery charger/power supply is a three-state charger (see text) and power supply regulator. When ac power is present, the battery is charged and the three-terminal regulator supplies power to the node. When ac fails, the battery supplies power to the node. If the battery should completely discharge, the relay will disconnect all loads from the battery, thus protecting it. A large output capacitor on the + 12VDC supply to the microprocessor voltage regulator supplies energy for the period of time it takes the relay to energize, preventing a momentary glitch in the +5VDC line.

voltage reference to accomplish this. An external pass-transistor increases the current handling capability to 1 amp. The relay/transistor circuit connects the battery to the load upon ac failure and disconnects the load when the battery is depleted.

Allowing the battery to remain connected to the load after it's depleted will destroy it. New Gel-Cel batteries can normally be expected to operate for six years when properly used; automotive-type batteries, which are designed for high surge currents, will normally have only about a three-year lifetime in a standby power applications and require different voltages. ***Warning: this circuitry is meant only for 12-volt lead-acid gel-cel batteries; its use is not recommended for any other type of batteries. Using Ni-Cad batteries with this charger could result in an explosion.***

references

1. Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5SEG, "The TEXNET Packet-Switching Network — Part 1: System Definition and Design," *ham radio*, March 1987, page 29.
2. Steve Good, K9NG, "Modifying the Hamtronics FM-5 for 9600 BPS Packet Operation," *Fourth ARRL Amateur Radio Computer Network Conference Proceedings*, page 45-51.
3. R. Valley, "IC Provides Optimal Lead-acid Battery Charging Cycles," *EDN*, October 31, 1985, page 163.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

grounding, shielding, and isolating: part 1

Most users of electronic equipment have to face problems of grounding, shielding, and isolating in order to prevent EMI (electromagnetic interference). Amateur Radio operators have an especially difficult problem because their equipment often must operate on the same desk as their high power radio transmitters. EMI is also caused by local electrical disturbances such as arcs, lightning discharges, and electrical motors.

The flip side of the EMI problem is prevention of interference to other equipment — such as televisions, radios, stereo systems, and other entertainment equipment — caused by Amateur transmitters. We must operate our stations in a manner that won't interfere with properly designed, properly operated equipment that's in good repair. Electronic equipment must do two things: respond to desired signals and reject undesired signals. There's not much we can do if the equipment fails to do the latter; if it meets both tests, however, our efforts can help profoundly.

In this installment, we'll discuss methods of preventing interference from outside and cross-interference between circuits or equipment in our own stations.

preventing EMI

Shielding and filtering of signal lines is the key to preventing EMI. **Figure 1** shows a "generic" electronic device with several of the possible EMI protection methods used. This type of circuit could be a microphone input preamplifier, a receiver accessory, or some other piece of equipment. First, note that the entire instrument is built inside a shielded metal box, and the box is grounded. Points of entry and exit incorporate feedthrough "EMI filter" capacitors (C_{FT}) (500 pF to 0.002 μF). Each stage is isolated from other stages by a resistor, and has its own decoupling capacitor (C5 and C7). The main power bus is decoupled (C6), and has a series rf choke (RFC2) to filter rf that gets past C2 and prevents it from interfering with the operation of the circuit. The input leads are similarly filtered with RFC1 and C4. The input resistance R_{IN} of the amplifier and the reactance of capacitor C4 also form a low-pass filter with a frequency response that rolls off at a 6 dB/octave rate from the −3 dB point defined by:

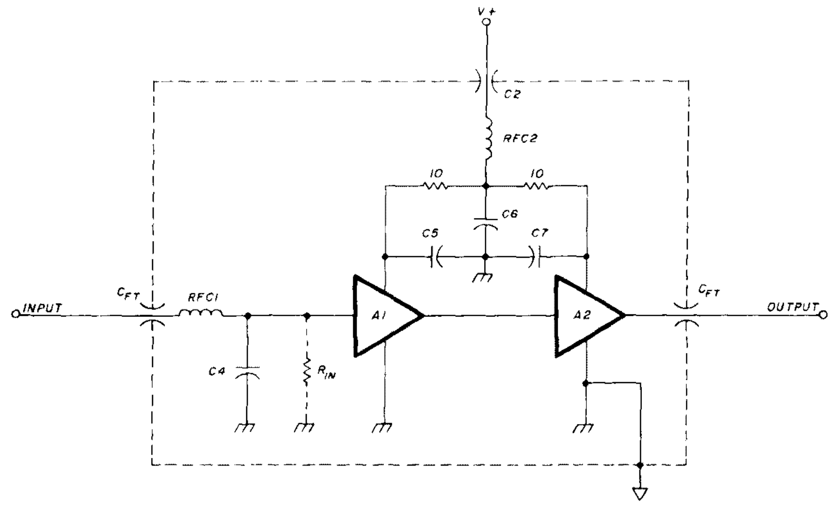


fig. 1. "Generic" electronic circuit showing EMI protection methods.

$$f(Hz) = \frac{10^6}{6.28 \cdot (C4)\ (R_{IN})}$$

where: f is the frequency in Hz, C4 is in μF, and R_{IN} is in ohms.

One potential source of interference is noise and other EMI signals on power lines. I can recall troubleshooting digital instrumentation and computers in a medical school building. We found that the ac power lines were the source of the problem. Where sensitive electronic instruments are used, one might want to consider designing the electrical system to be either isolated from the building system or have separate neutral and ground conductors all the way back to the building's electrical service entrance ground.

Figures 2 and **3** show methods for dealing with power line noise. In **fig. 2**, we see an LC power line filter. Although the version shown here uses just one LC section, others are available (at higher cost) with two or more sections. These devices are shielded low-pass filters, and are mounted inside equipment as close as possible to the point where ac enters the cabinet.

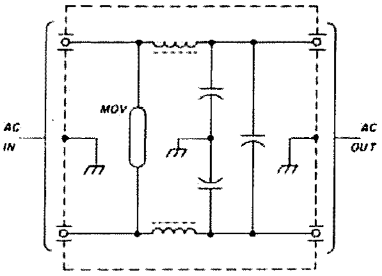


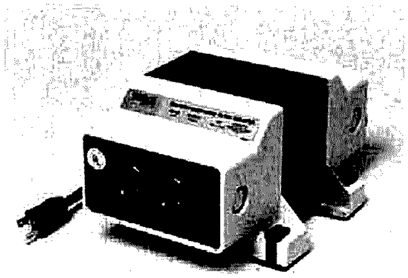
fig. 2. LC EMI filter for ac power lines.

Some filters are available molded into the ac chassis connector.

Also in the circuit is a Metal Oxide Varistor (MOV) device used to suppress ac line transients above about 155 volts peak (some can reach 2000 volts for 30 microseconds). Power line transients can have surprisingly sharp rise times, and thus are capable of producing interference across a wide portion of the spectrum. Because of this some designs have these MOV devices ahead of the filter in order to reduce the intensity of peaks that contain high frequency components.

There is an issue regarding EMI filters that some people overlook: fusing. Ideally, the fuse should be as close as possible to the point where the ac line enters the cabinet. If the fuse is placed downstream from the filter, the equipment won't be protected if components of the EMI filter short to ground. If the ac power line is routed through the fuse holder before passing through the EMI filter, on the other hand, there's enough prefiltered wiring to form an antenna and radiate into the other circuits. As a result, I prefer to build the fuse either into the EMI filter (or an extra shielded compartment that also houses the EMI filter) or into a fused ac plug at the wall outlet.

The Topaz transformer shown in fig. 3 performs three functions. First, it isolates the equipment electrical system from the ac electrical system. Second, it frequency-limits the system to prevent high frequency transients and pulses from passing into the equipment. Third, it provides a locally isolated ac power mains system that isn't ground referenced, making death or serious injury less likely in the event of accidental contact with the 110 or 220 volt ac lines. *All workbenches should have isolated power.*


Power line isolation transformer (Courtesy Topaz Electronics, San Diego, CA).

My opinion, which is shared by many others, is that no computerized or other digital equipment — or many types of analog and rf equipment — should be operated in a noisy power line environment without one of these transformers. This is especially true if

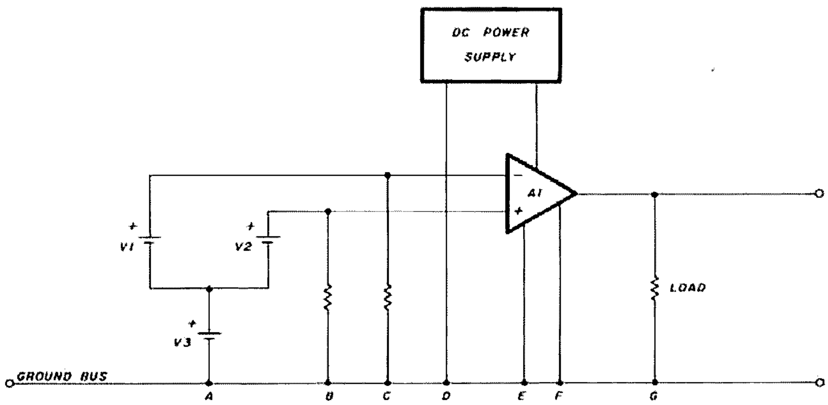


fig. 4. Ground loop problem results from too many ground points.

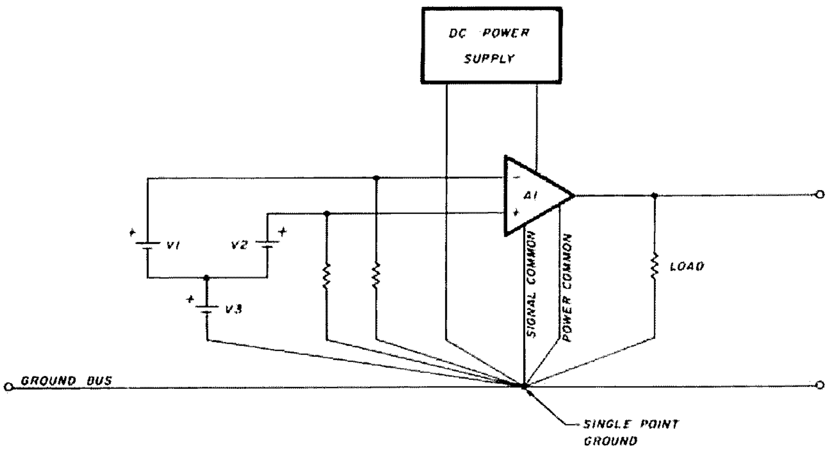


fig. 5. Single-point grounding solves ground loop problem.

(continued from page 4)

220 AT RISK—ACT NOW

with radiolocation through 1990, when that use will be largely phased out). Not a bad tradeoff, to go from 5 MHz (shared with two other hungry services and thus a potential roosting place for every channel-seeking schemer who's come along in the last decade) to a 3-MHz band that's as firmly ours as any Amateur band can be, and thus likely to stay that way for the foreseeable future!

But this is not 10 years ago, and that "lightly occupied" 220-225 MHz band is indeed *fully* occupied, particularly in most major urban areas. Even without Novice enhancement, the proposed reallocation will cause severe disruption to important, established Amateur activities. With the addition of Novice operators to the already crowded — not "lightly loaded" — 220 MHz band, perhaps the pundits who thought this one up will then decide that it's really 2 meters that's "lightly loaded" and declare that 2 meters is the one to be shared with others!

Can this proposal be stopped? Very possibly not — but every effort must be made and made *quickly*. ***The deadline for comments on General Docket 87-14 is April 6***, though several petitions to have this date extended are being filed. A minimum of one original and five copies of your comments are required; 11 copies are necessary if you wish each Commissioner to receive one. To be effective, cite occupancy facts and support use projections. "You can't do this to us!" isn't a very valid argument in Washington!

The FCC does indeed giveth . . . and may well taketh away, too!

— **Joe Schroeder, W9JUV**

short circuit

W6SAI

The inset table shown in **fig. 1** of W6SAI's February, 1987, column ("Ham Radio Techniques," page 45) should be corrected to read as follows: Tuned input network to match 420 ohms ($Q = 4$)

f(MHz)	C_1(pF)	C_2(pF)	L_1(μH)
3.5	605	361	6.30
7.0	302	180	3.15
14.0	151	90	1.57
21.0	100	60	1.05
28.0	75	45	0.79

SHORT CIRCUIT HOTLINE

Building a current *ham radio* project? Call the Short Circuit Hotline any time between 9 AM and Noon, or 1 to 3 PM — Eastern time — *before* you begin construction. We'll let you know of any changes or corrections that should be made to the article describing your project.

(See "Publisher's Log," April, 1984, page 6, for details.)

603-878-1441

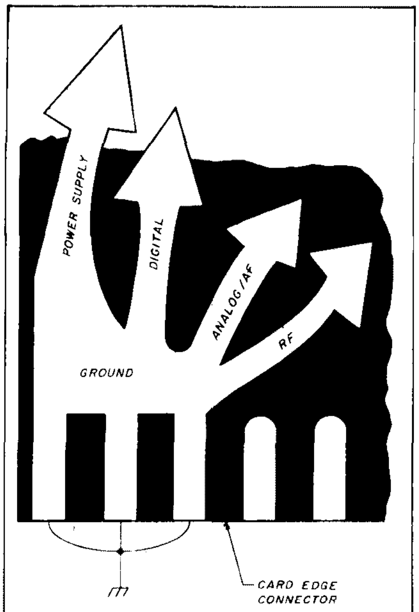


fig. 6. Single-point grounding on a printed circuit board.

the operation of the equipment is critical.

Although most Amateur equipment doesn't fall into this category, there are some cases where it might. For example, suppose you have a computer-controlled repeater transmitter. A power line transient could easily upset the program, causing it to "bomb" with the transmitter on . . . with no way for a control operator to turn it off without a personal visit to the site. While this problem is easily overcome by good design, I was told of one such situation in the Midwest, so I have to assume that others may also encounter it.

common-mode rejection

Other electrical devices nearby, as well as the ubiquitous 60-Hz field from building wiring, can induce signals into audio and low-frequency amplifier in-

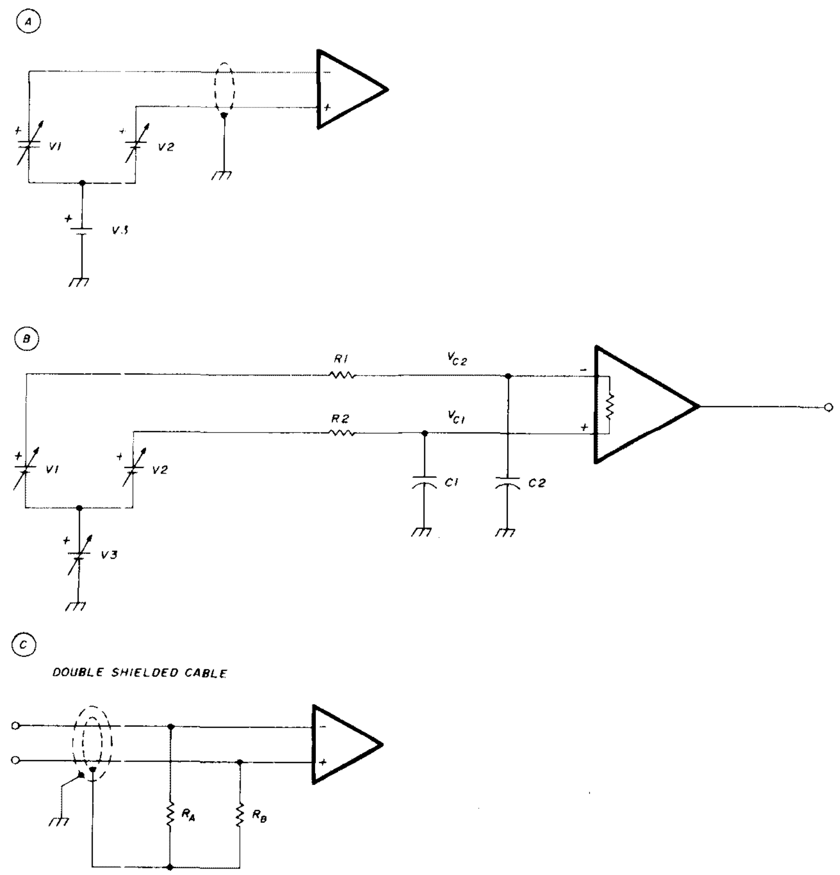


fig. 7. Common-mode problem and corrective procedures: (A) Shielded input stage; (B) equivalent circuit; (C) guard connection.

puts. It's wise to use differential amplifiers (where possible) for these applications because of their high common-mode rejection ratio (CMRR). Signals from desired sources are connected as differential signals (V1 and V2 in **fig. 4**) across the two inputs, while interference from the 60-Hz lines tends to be common mode because it affects both inputs equally.

It's sometimes possible, however, to manufacture a differential signal from a common-mode signal. This can occur in two ways; both involve the improper use of shields. One source of the problem is the ground loop, as shown in **fig. 4**. This problem arises from the use of too many grounds. In this example the shielded source, shielded input lines, the amplifier, and the power supply are all grounded to different points on the ground plane. Power supply dc currents flow from the power supply at point "D" to the amplifier power supply common at point "F," forming a voltage drop along the way. Similarly, other sources also cause ground plane voltage drops. Known as ground loop signals, these signals form valid input signals from the amplifier's "point of view."

The cure for ground loop signals is shown in **fig. 5**. In this example we see that all of the ground connections within the equipment are routed to a single common grounding point. This effectively eliminates the ground loop voltage drops. Also, note that rather than allowing each line to have its own shield, a single shield around both lines is used.

When you're designing a new system — and have the opportunity to design the printed circuit boards — make sure that single-point grounding is used. **Figure 6** shows a method for minimizing the noise problems in a circuit board. Note that four different grounds are used: one each for the power supply, the digital signal, the analog signal, and rf. All four grounds are joined together at a single point on the card edge connector and then spread out to their respective circuits.

common-mode signals

Figure 7 shows the causes and cures for another form of signal error: common-mode signals *manufacturing* differential signals. The circuit in **fig. 7A** uses standard single shielding, but the equivalent circuit shown in **fig. 7B** reveals the problem. The shield produces a capacitance to ground with the input wires (C1 and C2). In addition, there are cable and source resistances in the circuit, represented in **fig. 7B** as R1 and R2. The system works well if R1/XC1 = R2/XC2, but even small imbalances in the RC networks will allow common-mode voltages to manufacture a differential signal. In that case, it's found that V_{C1} does not equal V_{C2} so the amplifier sees what it accepts as a valid input signal.

A "guard shield" (**fig. 7C**) circuit can be used to overcome this problem. The guard shield is driven by signals from the two input lines summed together through high-value resistances, R_A and R_B and, in many

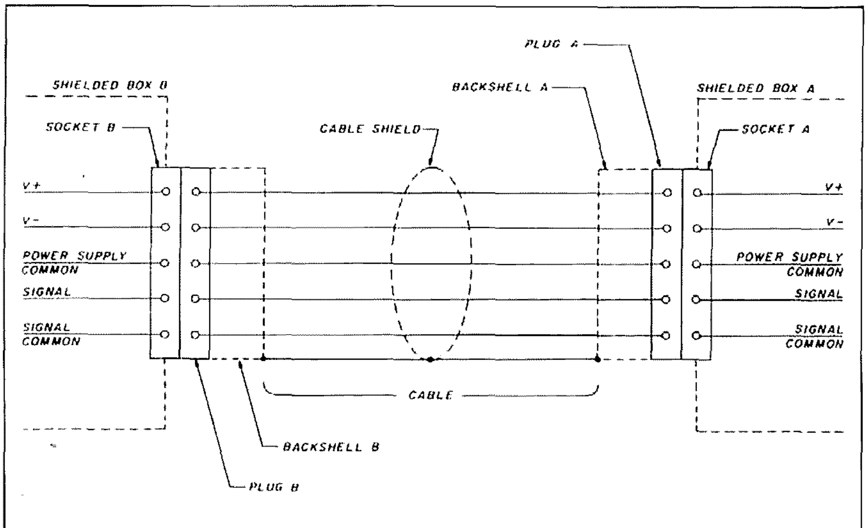


fig. 8. Method for connecting multi-conductor cable between equipment.

cases, a unity gain common-mode amplifier. The method has the effect of placing both sides of the cable capacitances at the same potential, so $V_{C1} - V_{C2} = 0$. The outer shield isn't strictly necessary, but is highly recommended in rf-rich environments.

don't run signals through shields

Another shielding scheme for connecting two pieces of related equipment is shown in **fig. 8.** This situation involves two pieces of equipment (identified here as "A" and "B") that pass multiple connections back and forth, including signals and power. While traditionally not common in Amateur equipment, this arrangement is becoming more so with the increasing use of interfaces between computers and Amateur Radio equipment (as in packet radio). A common error made in constructing the multiconnector cables is to pass signal or power common return paths through the shield itself. All such common paths should have their own separate wire in the cable bundle. Some internal conductors may be individually shielded. The shield is connected to the shielded backshells of each connector, but doesn't carry signals. It's sometimes permissible to ground the shield to the chassis through a pin in each connector, provided that it too does not carry signals or power.

Next month, we'll take a look at station grounding and other methods of preventing TVI that we might cause.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

Xingiang Province: the last frontier

At last! I'd stuck the final red pin in the map of the world. Covered with red pins, one for each DX country confirmed, and hung proudly on the wall of the operating room, it instantly showed visitors my DX prowess.

I had some good ones. Andaman Islands? *Yes.* Burma? *Yes.* Franz-Joseph Land? *Yes.* Tibet? *Yes.* Hours of DX operation had covered the map except for a gaping hole near the center of Asia. A no-man's-land of zero Amateur activity! I'd worked many stations around the perimeter of this mysterious "black hole," which measured about 600 miles in diameter.

This blank zone encompassed what was once known as "Chinese Turkestan," with the city of Urumchi — now known as Urumqi — as the focal point of interest. Located in western China, nestled between India and the USSR, Xinjiang Province (as it's now known) has never, as far as I know, been on the ham bands. (There was a rumor, circa 1948, of a certain C5YY who was supposed to be active from Urumchi, but nothing ever came of this story.)

Rumor has it that a new station will soon be on the air in the western section of the People's Republic of China using the call BY0AA. Perhaps this will be the station to represent the last frontier of DX — Xinjiang Province!

intermediates and prefixes

What seems simple now was rather complicated in the early days of radio. For example, you hear G6ZO working KH6BZF. You know it's a QSO between England and Hawaii by the prefix letters of the calls. Easy. But return, in your mind's eye, to the early days. When Amateur Radio began back before World War I, the infant hobby had no assigned call letters. Hams used their initials or an abbreviation of their town or city. SNJ was in Hartford and HU was in Honolulu.

Table 1. Post-World War I international Amateur call numbers.

Number	Country
1	Italy, Luxembourg
2	England
3	Poland
4	Germany, Belgium
5	England
6	England
7	Denmark
8	France
9	Switzerland
0	Netherlands

Table 2. Original Amateur international intermediates (reprinted from *QST*, March, 1923).

A—Australia
AU—Alaska*
B—Belgium
BE—Bermuda
BZ—Brazil
C—Canada and Newfoundland
CH—Chile
CR—Costa Rico
D—Denmark
E—Spain
F—France
PI—French Indo-China*
G—Great Britain
GI—Ireland*
H—Helvetia (Switserland)
HU—Hawaiian Islands
I—Italy
IC—Iceland*
J—Japan
K—Germany
L—Luxembourg
LA—Norway*
M—Mexico
N—Netherlands
O—South Africa
P—Portugal
PE—Palestine*
Q—Cuba
B—Argentina
S—Scandanavia (Denmark, Finland, Sweden)
SR—Republic of Salvador
U—United States
Y—Uruguay
Z—New Zealand

*These intermediates have been self-assigned and are unofficial. They are in more or less general use, however.

Just before the war, licensing was instituted in the United States and call areas were initiated. About the same time, this happened in other countries. After the end of World War I, when Amateurs returned to the air, the situation was much clearer. In Europe, an agreement between countries assigned numbers to various countries

Table 3. "New" international intermediates (reprinted from *QST*, January, 1927).

54 QST January, 1927

NEW INTERNATIONAL INTERMEDIATES, EFFECTIVE 0000 G.M.T., FEB. 1, 1927.

EUROPE

EA—Austria
EB—Belgium
EC—Czechoslovakia
ED—Denmark and Faroe Ids.
EE—Spain and Andorra
EF—France and Monaco
EG—Great Britain and Northern Ireland
EH—Switzerland
EI—Italy
EJ—Jugo-Slavia
EK—Germany
EL—Norway, Spitsbergen and Franz Josef Land
EM—Sweden
EN—The Netherlands
EO—Irish Free State
EP—Portugal, Madeira Ids., and the Azores
EQ—Bulgaria
ER—Rumania
ES—Suomi (Finland)
ET—Poland, Esthonia, Latvia, Courland and Lithuania
EU—U. S. S. R. ("Russia"), including Ukraine
EV—Albania
EW—Hungary
EX—Luxemburg
EY—Greece
EZ—Zone of the Straits

ASIA

AA—Arabia
AB—Afghanistan
AC—China (including Treaty Ports), including Manchuria, Mongolia, and Tibet.
AD—Aden
AE—Siam
AF—French Indo-China
AG—Georgia, Armenia and Azerbaijan
AH—Hedjaz
AI—India (and Baluchistan) and Goa
AJ—Japan and Choaen (Korea)
AK—(Unassigned)
AL—(Unassigned)
AM—Federated Malay States (with Straits Settlements)
AN—Nepal
AO—Oman
AP—Palestine
AQ—Iraq (Mesopotamia)
AR—Syria
AS—Siberia, including "Central Asia"
AT—Turkey
AU—(Unassigned)
AV—(Unassigned)
AW—(Unassigned)
AX—(Unassigned)
AY—Cyprus
AZ—Persia

NORTH AMERICA

NA—Alaska
NB—Bermuda Id.
NC—Canada, Newfoundland and Labrador
ND—Dominican Republic
NE—(Unassigned)
NF—Bahama Ids.
NG—Guatemala
NH—Honduras
NI—Iceland
NJ—Jamaica
NK—(Unassigned)
NL—Lesser Antilles
NM—Mexico
NN—Nicaragua
NO—British Honduras
NP—Porto Rico and Virgin Ids.
NQ—Cuba and Isle of Pines
NR—Costa Rica
NS—Salvador
NT—Haiti
NU—United States of America
NV—(Unassigned)
NW—(Unassigned)
NX—Greenland
NY—Panama
NZ—Canal Zone

SOUTH AMERICA

SA—Argentina
SB—Brazil, Trinidad Id., and St. Paul Id.
SC—Chile
SD—Dutch Guiana
SE—Ecuador and Galapagos Archipelago
SF—French Guiana
SG—Paraguay
SH—British Guiana
SI—(Unassigned)
SJ—(Unassigned)
SK—Falkland Ids. and Falkland Dependencies
SL—Colombia
SM—(Unassigned)
SN—Ascension Id.
SO—Bolivia
SP—Peru
SQ—(Unassigned)
SR—(Unassigned)
SS—(Unassigned)
ST—(Unassigned)
SU—Uruguay
SV—Venezuela and Trinidad
SW—(Unassigned)
SX—(Unassigned)
SY—(Unassigned)
SZ—(Unassigned)

AFRICA

FA—Abyssinia
FB—Madagascar, Reunion Id., Comoro Id., etc.
FC—Belgian Congo, Ruanda, Urundi
FD—Angola and Kabinda
FE—Egypt
FF—French West Africa, including French Sudan, Mauritania, Senegal, French Guinea, Ivory Coast, Upper Volta, Dahomey, Civil Ter. of the Niger, French Togoland, etc.
FG—Gambia
FH—Italian Somaliland
FI—Italian Libya (Tripolitania and Cyrenaica)
FJ—Somaliland Protectorate and Socotra
FK—Kenya, Zanzibar Protectorate, Uganda, Anglo-Egyptian Sudan, and Tanganyika Territory.
FL—Liberia
FM—Tunisia, Algeria, Morocco (including the Spanish Zone), Tangier
FN—Nigeria
FO—Union of South Africa, Northern and Southern Rhodesia, Bechuanaland Protectorate, and Southwest Africa
FP—Portuguese Guinea and Cape Verde Ids.
FQ—French Equatorial Africa and Cameroons
FR—Rio de Oro and adjacent Spanish Zones, Ifni, and Canary Ids.
FS—Sierra Leone
FT—Eritrea
FU—Rio Muni (Spanish Guinea) and Fernando Po
FV—French Somaliland
FW—Gold Coast Colony, Ashanti, Northern Territories and British Togoland
FX—Seychelle Dependencies
FY—(Unassigned)
FZ—Mozambique

OCEANIA

OA—Australia (and Tasmania)
OD—Dutch East Indies*
OE—Melanesia*
OH—Hawaiian Ids.
OI—Micronesia*
OO—Polynesia*
OP—Philippine Ids.
OZ—New Zealand
* To be further partitioned when activity warrants.

SHIP STATIONS

Ship stations with amateur calls will place an X before their usual intermediate. E. g., Australian 3AA at sea, calling U. S. 1AW, would send "1AW NUXOA 3AA" The reply would be "3AA XOANU 1AW".

(see **table 1**.) By 1923, this system had been replaced by letters, and calls began to resemble those with which we're familiar today. An interesting identification scheme was adopted; these new "intermediates," as they were called, are listed in **table 2**.

Viewed from today's perspective, the use of the intermediate, written as a lower case letter, seems strange. English 6ZO would have had an intermediate call of g6ZO. But the intermediate wasn't sent *with* the call, but instead was combined with the intermediate of the station being called. For example, assume English 2SZ was calling New Zealand 4AA. The call sequence would have gone like this: 4AA 4AA 4AA zg 2SZ 2SZ 2SZ. When 4AA replied to 2SZ, the sequence was: 2SZ 2SZ gz 4AA 4AA.

This didn't lead to rapid, simple exchanges of QSOs, but it was a step in the right direction.

By 1927 the International Amateur Radio Union started a serious program to straighten out the international identification of Amateur calls. A new list was formed (**table 3**). The first letter of the prefix denoted the continent and the second the country. The cumbersome intermediate scheme still was used, but some hams were signing their call and intermediate together and using the French word "de" (from) between the call of the sending station and the station being called, much as is done today.

The United States intermediate "U" was replaced with "NU." Shortly thereafter, the Government started issuing full calls with the prefix letter "W" denoting the United States, as determined by the International Telecommunications Union. The old intermediate system faded into oblivion: government assigned prefixes were in use, and the intermediate "de" was accepted by Amateurs worldwide.

It wasn't an easy task to arrive at internationally accepted call letters. As I said, what seems so simple now was very complex in the early days.

Some old timers have lived through all the call letter changes. The famous call AC4YN was in use until the postwar period when China took over control of Tibet. The old prefix "FB," for Madagascar, was in use until that country achieved independence from France.

So the next time you hear an unusual prefix on the band, you can appreciate the years of trial-and-error effort that went into establishing a workable call sign system.

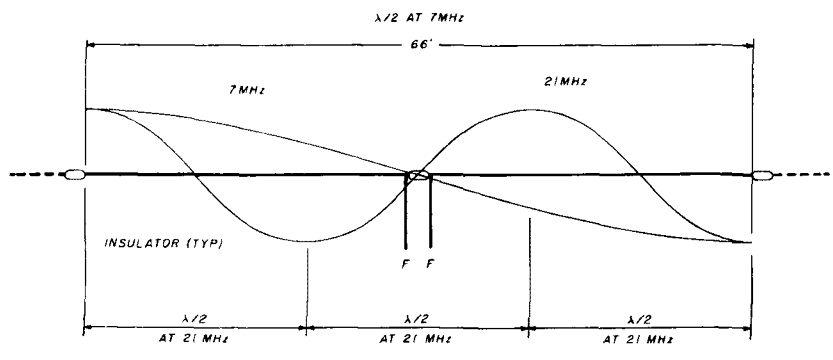


fig. 1. 40-meter dipole showing voltage distribution for fundamental and third harmonic waves (F − F = Feedpoint).

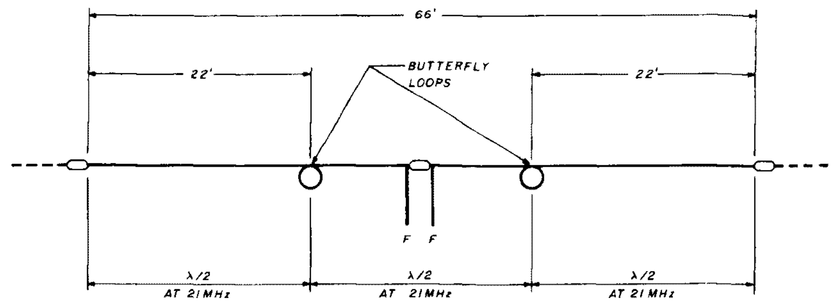


fig. 2. "Butterfly Loops" placed at high potential points along harmonic antenna lower harmonic resonance with little effect upon fundamental frequency resonance.

wire multiband antennas

It's well known among Amateurs that a center-fed dipole antenna will work (almost) on its third harmonic. Some hams have had good success using a 7-MHz dipole on the 21-MHz ham band. Unfortunately, because of end effects, the dipole isn't exactly resonant at the third harmonic, but at some frequency slightly above it. Thus a dipole cut for 7.1 MHz will be resonant at a frequency higher than the 21 MHz band. For resonance on the third harmonic, the wire should be 68.46, not 66 feet long (**fig. 1**). The general formula for a harmonic antenna is:

$$Length\ (feet) = \frac{492\ (N - 0.05)}{f\ (MHz)}$$

where N is the number of half waves in the antenna.

This formula holds true when the antenna is a straight wire. But what happens when the wire is bent back upon itself? Or, what happens when the wire is artificially loaded for harmonic resonance?

harmonic "loading"

Let's take the case of the 7-MHz dipole (**fig. 2**). As is, its fundamental resonance is 7.1 MHz. Its third harmonic resonance is 21.95 MHz. The problem is to load the antenna to a lower frequency in the 21-MHz region without

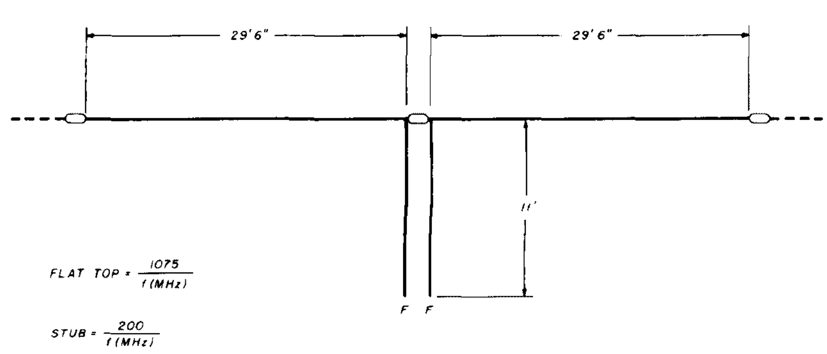


fig. 3. Two-band antenna for 18.1 and 28.5 MHz. Antenna is fed with 1:1 balun and coax at F – F.

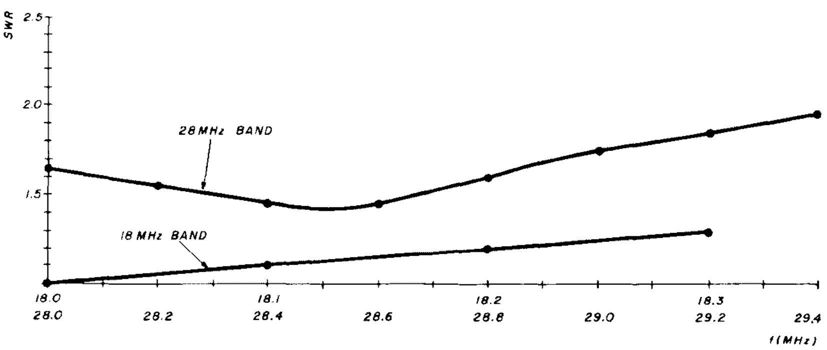


fig. 4. SWR curves for two-band antenna.

disturbing its resonance in the 40-meter band. This can be done by attaching "butterfly loops" at the high voltage points in the antenna corresponding to 21 MHz operation. The loops will have little, if any, effect on 7-MHz operation. The size of the loops must be determined experimentally, and they should be equal in size. The loop need not be round — almost any shape seems to work, and resonance is adjusted by changing the shape and size of the loop. I made my loops out of No. 12 enamel wire, with a diameter of about 1 foot. The loops were attached to the flat-top temporarily by means of small copper battery clips. After loop placement was adjusted for resonance at 21.2 MHz, the loops were soldered permanently to the antenna wire. I varied the loop diameter several times before I finally hit resonance (as determined by an SWR meter) at my chosen frequency in the 15-meter band.

Another situation where this idea would work is the case of a 10-MHz dipole, whose third harmonic resonance is well above 30 MHz. It should be possible to place loading loops at the 10-meter high voltage points in the flat-top to bring antenna resonance within the 10-meter band. Someday I'm going to try this interesting antenna. If you hear me, you'll know the scheme works!

another two-band antenna

I have an experimental license (KM2XDW) for conducting tests on 18 MHz. Although most of the time I've used a dipole antenna, I've recently experimented with half-waves in phase, as shown in **fig. 3**. The old reliable "two half-waves in phase" design has been used for many years; unfortunately such an antenna cut for 18 MHz just wouldn't fit into the restricted space in my backyard. The solution was to make the flat-top shorter and increase the length of the folded center section. This section acts somewhat in the manner of a matching transformer, allowing the antenna to be fed with a 1-to-1 balun and a coax line.

The antenna, cut to fit the space, and its dimensions are shown in the drawing. Interestingly, it was found that the antenna also exhibited resonance in the 10-meter band! By luck, the total wire length in the antenna was just about 1-1/2 wavelengths on 10 meters. The VSWR curves for 18 and 28 MHz are given in **fig. 4**. Using the formulas given in **fig. 3**, the antenna may be cut for any two frequencies that have the ratio of 1.57 to 1. Thus, an antenna cut for 14 MHz will also present a second resonance at 14 x 1.57 = 21.98 MHz. That's a little too high in frequency to be of practical use, but by adding butterfly loops at the high voltage points on the wire for the harmonic frequency, that resonance can be lowered to the 21-MHz band with little, if any, effect on 14-MHz operation.

general case

These antenna examples show that by changing the shape of a long wire, and by adding capacitance at the high voltage points at a harmonic frequency, the higher resonance point may be moved about. The idea that resonances in a long wire fall only at approximate multiples of the fundamental frequency applies only when the wire lies in a straight line. In addition, the harmonic resonant frequency determined by the configuration of the wire can be further manipulated by proper application of capacitance loops. If you want a simple multiband antenna, center-fed with a coax line, you can run your own experiments along the lines of those shown here. Armed with an SWR meter and a notebook for keeping records of your experiments, the sky's the limit!

ham radio

a three-tube 4CX250B linear amplifier

Who says nobody builds any more?

I had considered building a 2-meter linear amplifier using three 4CX250B tubes for some time. Initial calculations indicated that I could achieve good performance if I could simply translate a design on paper into an actual working unit.

To simplify the design effort I wrote a computer program that would perform precise calculations and simulations of plate and grid line operation for various operating conditions such as different plate voltages and currents, tight or loose coupling with the antenna, or reactive antenna impedances. Doing this yielded optimum *Qs* and efficient line values.

Many hams and clubs in Yugoslavia were interested in the design. Sketches were copied and distributed, and amplifiers built and tried. The initial design worked as planned. Modifications have since been incorporated; this article decribes the best and final design. Several other published designs were checked against the computer program and found not to be optimum.

three tubes in parallel

This amplifier uses three tubes in parallel in which the screen is at both DC and RF ground potential. Many hams who have tried to build around the 4CX250B have given up because of the unavailability or cost of the sockets. Grounded screen operation offers a viable yet inexpensive alternative, provides stable operation, and requires no sockets.

Though the mechanical layout may seem primitive to the sophisticated VHF builder, it's really simple and efficient. Tube replacement is somewhat more difficult than with sockets, but it can be done quickly once you get used to it.

voltages

A schematic of the completed amplifier is shown in **fig. 1**.

The cathode is at −350 volts and the grid at −400 volts with respect to the screen (remember, it's grounded). To simplify the power supply design, voltage-dropping resistors (68k, 100W) and zener diodes are used. Additional protection is provided by slow-blow fuses. The plate voltage should not exceed 2.5 kilovolts unloaded and no less than 2.1 kilovolts loaded.

It's useful to include as many meters as possible — but if you choose not to, make sure that at least the plate and screen current are independently monitored.

Considering the relatively high voltage on the cathode, the filament transformer secondary should be well insulated from ground. One of the secondary leads is soldered directly to the tube pins and the other via a necessary RF choke.

RF section

The plate line is a quarter-wave section of stripline that is directly grounded at one end and connected to the tubes via a plate blocking capacitor, C_0 (see **fig. 2** for details). The quality, values, and placement of these capacitors are critical and should be carefully considered. The following conditions must be satisfied:

- high capacitance value resulting in less than one ohm of capacitive reactance
- high Q
- placement close to the tubes

The blocking capacitors used in this design consist of two metal plates with a teflon (PTFE) dielectric. The lower plate is grounded (plate strip L_a) while the other is connected to the tube plates. I used teflon foil which measured between 0.3 and 0.5 mm in thickness and was perfectly smooth, with neither cracks nor slots. The upper metal sheet is extended up to the grounded side of the plate line, thereby increasing capacitance and aid-

By Dragoslav Dobričić, YU1AW, St. Supljikca 105/8. 26000 Pancevo, Yugoslavia.

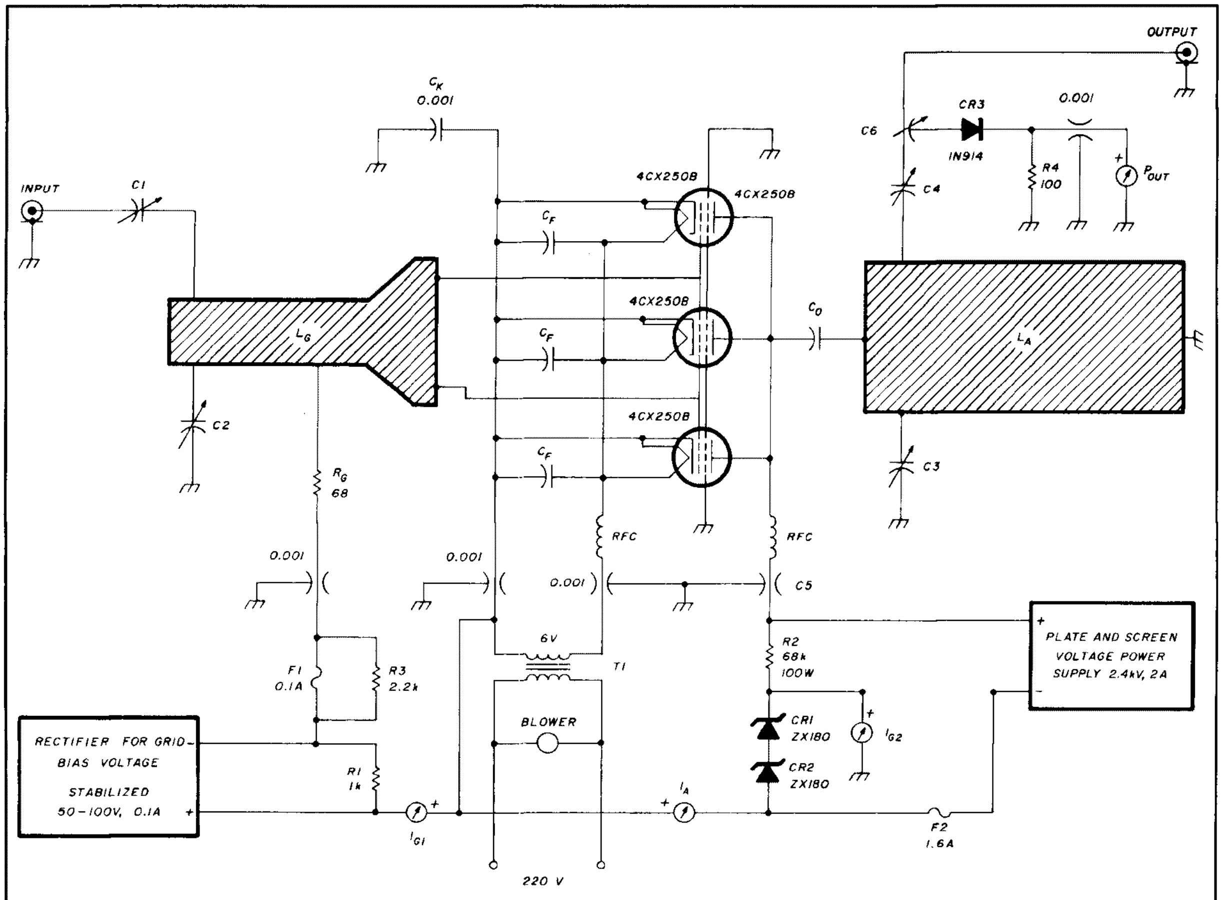


fig. 1. Schematic diagram of three-tube 4CX250B 2-meter linear amplifier.

ing in rf/dc isolation. An enlarged view is shown in **fig. 3**. Plate voltage is supplied through an RF choke to the location of lowest RF potential (almost zero). This improves amplifier stability while maintaining good RF/DC isolation.

Capacitor C5 (a section of single-sided glass-fiber PC board) is glued to the plate compartment wall and acts as a feedthrough capacitor. High voltage is introduced by means of a BNC connector. No additional steps are necessary to prevent feedback of the RF signal into the power supply.

As shown in **fig. 4** and **photo A**, there's an "ear" on both sides of the resonator, i.e., C4 and C5 stator plates. Rotor plates are soldered to the central pin of a female N connector (for C4) and grounded (for C5). Plate separation — and consequently capacitance — can be changed mechanically by adjusting a length of fishing line wrapped around a shaft made of brass or some insulated material.

The grid line is a half-wave 70-ohm impedance stripline used instead of the quarter-wave line because input capacitances are rather high (see **fig. 5** and **photo B**). An air-variable capacitor, C2, at the end of the line provides the resonant tuning control. Drive power is applied through C1 and bias is fed via a 68-ohm resistor at the point of minimum RF voltage. Using a resistor instead of a choke reduces the amplifier's tendency to oscillate. A resistor should always be used when high gain tetrodes are employed.

Grid connections are all soldered to the input strip through three small holes. C1 is connected to the input BNC connector with a length of coaxial cable with its plastic jacket removed (see **fig. 6**).

Cathode pins on the 4CX250Bs are 2, 4, 6, and 8. They should be connected together with a piece of copper strip the same width as the pin length. All number 3 pins should also be connected together and soldered to the cathodes. This places all cathodes and one side of all filaments at the same potential. Pin 1 is connected to the screen ring and can be used as a ground contact. Capacitor C_k should be connected between pins 1 and 2 using the shortest possible leads. Capacitor C_f should be connected between the remaining filament contact (pin 7) and pin 6 or 8. Pin 5 should not be used at all.

construction

Dimensions and details for the fabrication of the upper and lower plate, teflon spacer, grid line, and capacitors C3 and C4 are shown in **fig. 7**.

The amplifier cabinet is made from aluminum and has separate grid and plate compartments (**photo C**). Ventilation holes in the plate between the two compartments permit air flow; air enters the grid compartment, is brought up to cool the plates and then exhausted through homemade teflon chimneys.

Though the air flow path is rather long, there is a negligible drop in air pressure along the way compared to that experienced at the plate's cooling fins. The 4CX250B tubes require a good-sized squirrel cage blower to overcome this pressure drop (**photo D**). In addi-

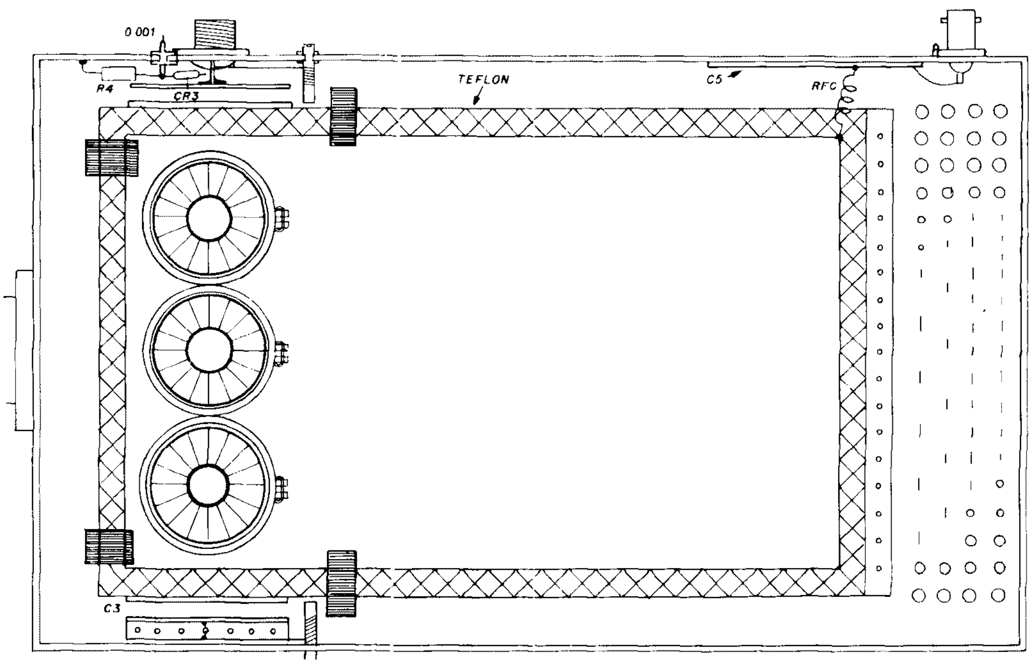


fig. 2. Method of grounding bottom plate line is shown on the right.

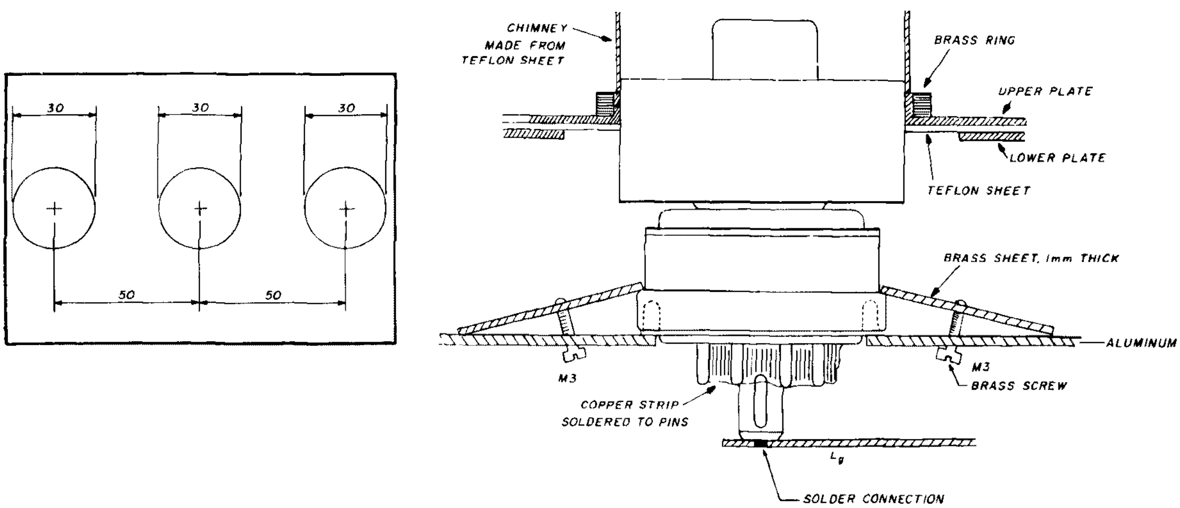


fig. 3. Clamping effect of brass sheets secures tubes. The hole pattern for the three tubes is shown in the inset. (Metric dimensions are provided; see page 72 for metric-English measurement conversion table.)

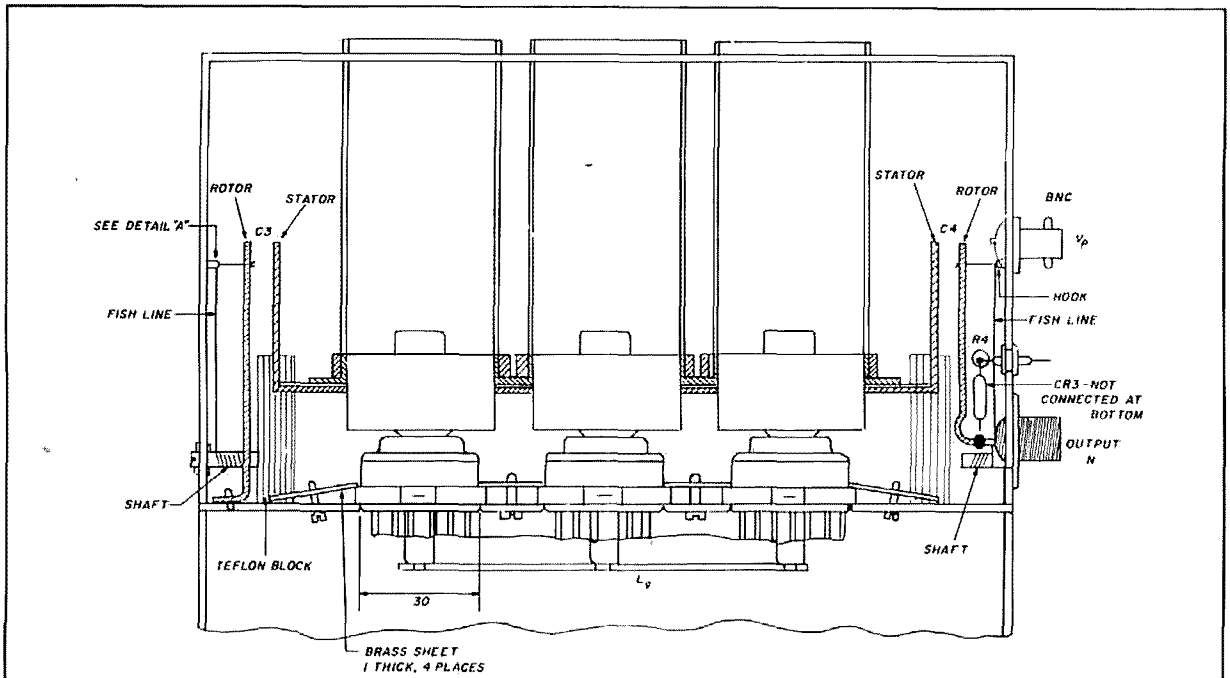
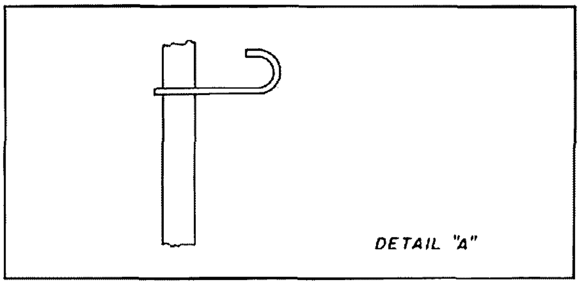


fig. 4. Side view illustrates C3 and C4 rotor/stator construction and attachment.



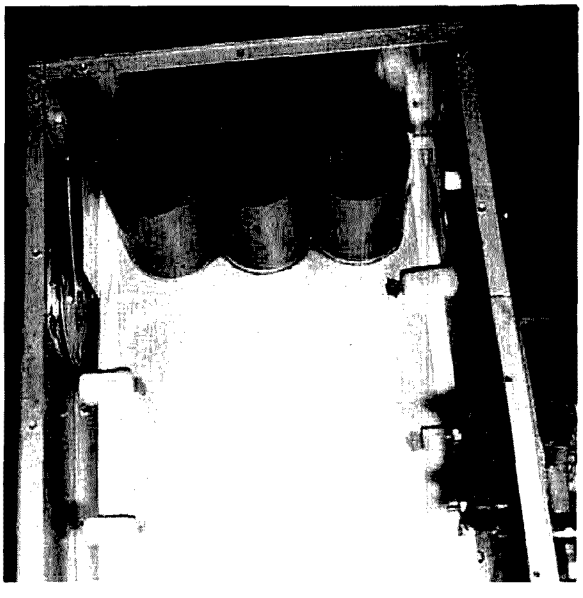


Photo A. Capacitance variation is achieved by mechanically adjusting length of fishing line.

tion, good sealing between the aluminum plates is needed to prevent leaks and subsequent loss in air pressure. Holes between compartments should be round rather than slotted because elongated holes could become slot antennas, causing oscillation as a result of plate/grid coupling.

The plate line resonator (lower plate) is joined to the shield with brass screws. Good bonding is essential because of high currents at this location, so be sure to use as many screws as specified. The upper and lower parts of the plate line are held in place with slotted teflon blocks that fit it securely to the resonator.

The tubes are mounted in the pre-drilled holes in the shield with the diameter chosen according to the screen ring dimensions. The screen ring is slightly larger than the ceramic body and good RF and DC contact is made. Each tube is secured at four locations and a single piece of brass is used to clamp adjacent tubes. To remove the tubes, reverse the procedure by loosening the clamps and rotating them 90 degrees. Do not apply too much pressure on the tubes because the screen ring could be damaged.

Plate chimneys are fabricated from thin teflon sheet rolled and clamped to fit the plate radiator diameter (see

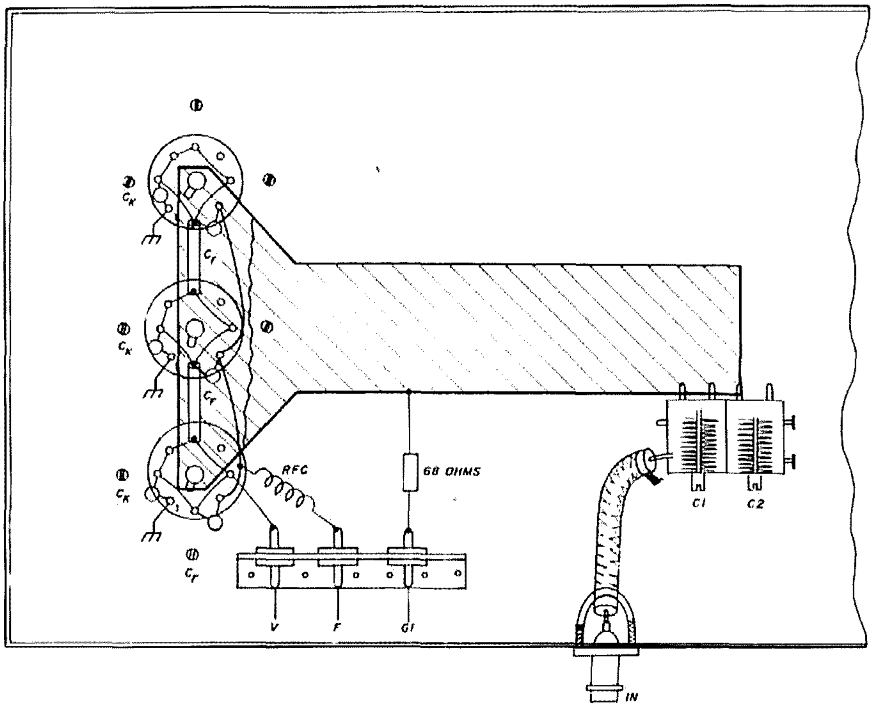


fig. 5. Half-wavelength grid line is utilized to handle high input impedances.

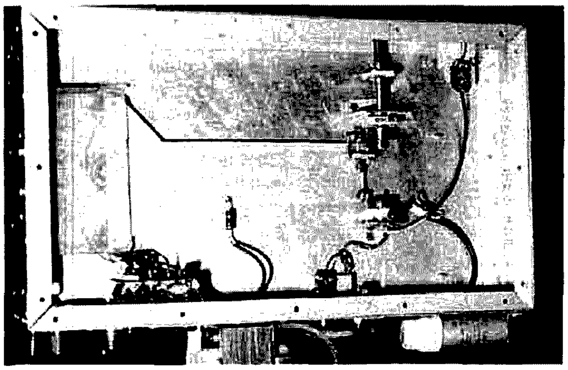


Photo B. Bottom view of grid compartment illustrates major component placement. Tube sockets are on the left.

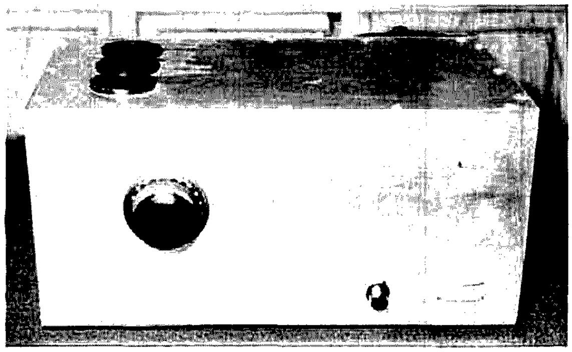


Photo C. Front view of 2-meter linear shows essentials are all there: input, tuning, and exhaust.

photo E). An even less expensive solution would be to use paper heavy enough to withstand the expected temperatures. The plates can be connected to the plate resonator using finger stock or other material. The most important requirement is that good electrical contact is made.

adjustments

Switch on the amplifier in the following sequence. Turn on the filament voltage, bias voltage, and blower. After a 1-minute warm-up, apply screen and plate voltage. If hash is heard in the receiver with the amplifier in standby mode (all voltages on), increase the bias voltage to −90 volts or more (negative). The bias voltage is normally adjusted for an idling plate current of 50 mA per tube.

Carefully increase the drive power while adjusting C1 and C2 for a plate current peak. Adjust C3 for a screen grid current peak, then repeat the first two steps with increased drive power. Adjust C4 for a final screen grid current of 8 mA per tube.

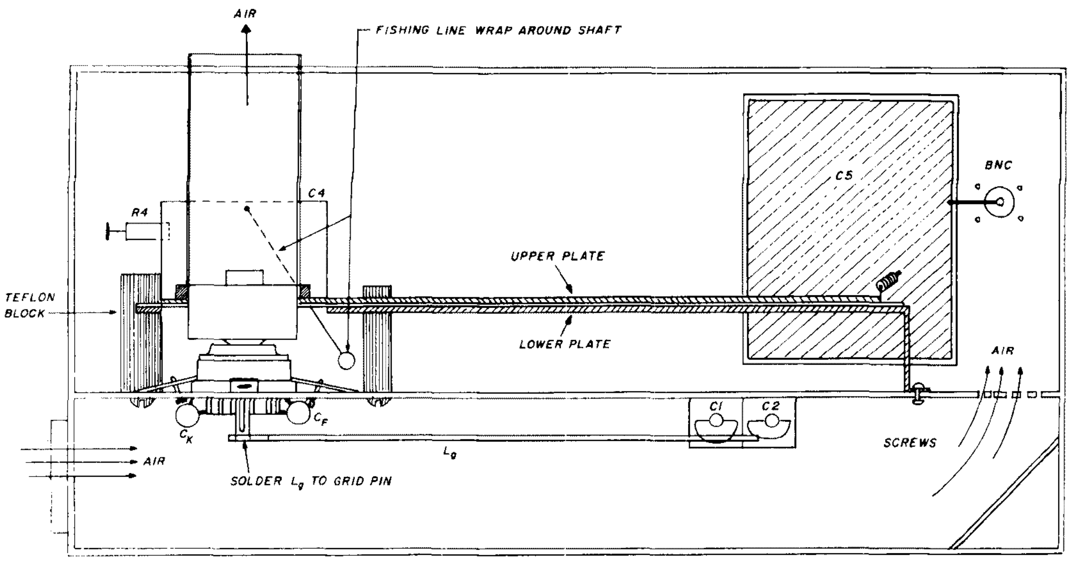


fig. 6. Side view illustrates grid connection, upper and lower plate connections, and air flow.

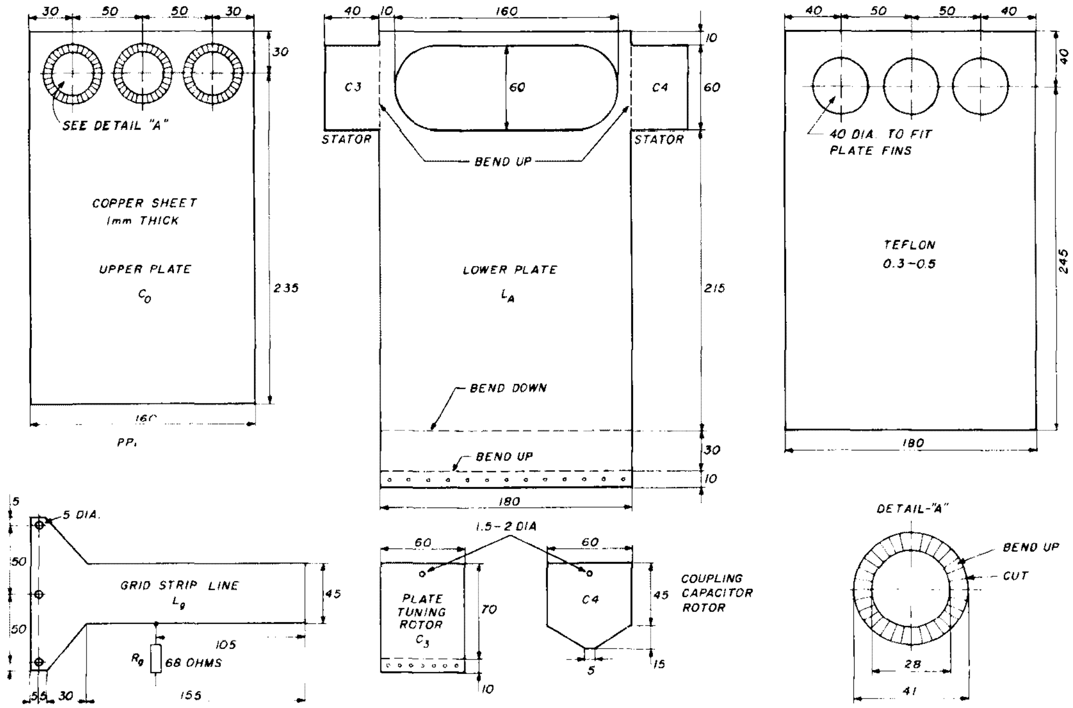


fig. 7. Dimensions are provided for constructing upper, lower plate, teflon insulating sheet, grid stripline, and C3, C4 rotor plates.

The final adjustments can be done by keying the amplifier with a series of dots (using an electronic keyer). This allows maximum drive voltages to be applied without exceeding maximum power dissipation levels. All meters should indicate approximately 35 percent of maximum value. Negative screen grid current means that the

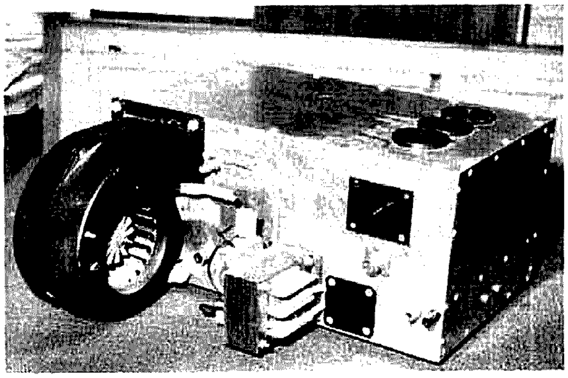


Photo D. Rear view of amplifier reveals same basic simplicity and effectiveness of construction.

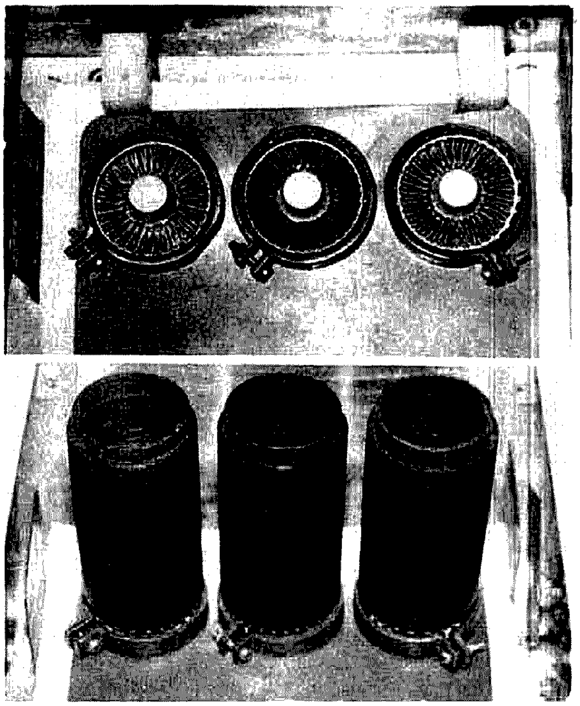


Photo E. "Before" and "after" views of chimney placement for the 4CX250B's.

drive power is too low and/or that the amplifier is too tightly coupled to the antenna.

single-tube SSB and CW ratings

At the ratings shown below, fm, a-m, RTTY, and SSTV operation are *not* recommended.

V_g1	= −65 volts
V_g2	= 350 volts
V_p	= 2.4 kV
I_g1	= 15 mA (max)
I_g2	= 8mA (max)
I_p	= 50mA (idle)
I_p	= 400mA (max)
P_{out}	= 650 watts (max)
P_{in}	= 960 watts (max)
P_{diss}	= 300 watts (max)
R_L	= 3.1 kilohms
Efficiency	= 68 percent

If all three tubes are closely matched, expect a tripling of output power and all currents. Equal power sharing (output) can be verified by measuring the temperature of air leaving the chimneys. If there appears to be an imbalance, increase idling current; the inequalities should become even more obvious.

determining component values

Computer simulation determined that the values of the following capacitors at resonance should be as follows:

C1 = 35 pF C3 = 3 pF
C2 = 10 pF C4 = 5 pF

Low losses, broad bandwidth, small temperature detuning, low RF voltages on the tube (resulting in longer life and little possibility of flashovers), and broad plate tuning make this a practical design. Note that all calculations were based on Eimac tube data and differences may occur if other manufacturers' tubes are employed.

Another useful feature of this amplifier is its low driving power requirement. Low cathode stray lead inductances help to reduce the drive requirements. It's possible to achieve between 1 and 2 dB of additional gain if a special effort is made to resonate (series) the value of C_k with the stray cathode lead inductances. It actually becomes necessary if you are drive-power limited.

additional hints

- Use as many screws as possible to join the cabinet together in order to reduce rf leakage.
- Use a type N — not an SO239 — for the output connector.
- Plate voltage may be supplied through a BNC connector and RG-58.
- Any departures from the dimensions called out on the drawings could result in degraded amplifier performance.
- The plate line should be cut from brass or copper sheet 1 mm thick and should be silver-plated, if possible.
- Both of the ZX180 zener diodes (180 volts, 12 watts) are mounted on heat dissipation devices.
- Other combinations of zener diodes or tube voltage regulators may be used to provide a regulated +360 volts.
- Resistor R3 (2.2 k) acts like a fuse, delivering bias if the "slowblow" 0.1 A fuse is blown.

Conversion table for dimensions mentioned in art for this project.

millimeters	*inches*
0.3	.012
0.5	.019
1.0	.039
1.5	.059
2.0	.079
5	.197
10	.394
15	.591
28	1.102
30	1.181
40	1.575
41	1.614
45	1.772
50	1.969
60	2.362
70	2.756
105	4.134
155	6.102
160	6.299
180	7.087
215	8.465
235	9.252
245	9.646

acknowledgments

I wish to thank all those hams who believed in this unusual design and had the courage to try it.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

33 cm: update

One year ago this column was devoted to our newest UHF band, 33 cm (902-928 MHz).[1] Since that time, much has happened on this band, which is now just over 18 months old. Activity is growing fast, but more activity could really help popularize the band.

Last year's column was intended to be an "entry level" article. In this month's column, I'll present further information that will upgrade some of the circuits and the antenna described in the earlier article. I'll also discuss some commercial gear that has recently become available. With luck, the new information will encourage increased activity by helping others to become active on one of our newest and most exciting UHF bands.

latest activity

Weak-signal operation on 33 cm has been reported in the W1, W2, W3, W4, W7, W9, W0, VE2, and VE3 call areas. (Did I miss anyone?) Most of the activity is reportedly on the calling frequency of 903.1 MHz, as recommended in last year's column. There are also several fm repeaters active in the upper portion of the band, two of which are in the W1 call area. A California and a Massachusetts ATV repeater have also been reported as active, so the band is obviously being used for purposes other than weak-signal operation.

As a sign of acceptance of 33-cm contacts, the ARRL now counts 33-cm contacts separately for new multipliers and points in VHF/UHF contests. 33 cm also has its own VUCC (VHF/UHF Century Club) award for those who've worked at least 25 grid squares on this band. Furthermore, the ARRL has announced that the Spring Sprint contests this year will include a separate 33-cm contest night. The tentative date is Friday, May 8, 1987 (7 to 11 PM, local time).

Several stations have also been active on portable expeditions. They've done quite well using low power (10 watts) and single 12-foot loop Yagi antennas. I've been successful in working only a few grids that way, so my total number of grids worked so far is a puny ten. However, while writing this month's column I heard that at least one ham has sent out several active "rovers" and worked the necessary 25 grids to claim the first 33-cm VUCC award.

propagation

Although initially some of us weren't sure what kind of propagation we'd experience on 33 cm, we expected it to be a blend of 70 (432 MHz) and 23 cm (1296 MHz). I think most of us now active on the 33-cm band feel that the typical propagation is more like 70 cm for casual contacts. Stations using 10 watts and a single 12-foot boom loop Yagi can easily cover a 100-mile range on SSB, with signal strengths as strong or stronger than can be anticipated on 70 cm.

Extended tropospheric propagation hasn't been well used because of the poor distribution of equipment available for 33 cm during the few openings this past year. The aurora, though absent in recent months, should return within the next year or two as solar cycle 22 begins. This will afford the best opportunity for auroral QSOs above 450 MHz, presently the highest frequency at which two-way Amateur QSOs have been reported in this mode.

Aircraft scatter propagation on 33 cm seems to be as good or better than on 70 cm and more like the conditions experienced on 23 cm.[2,3] Several stations have reported QSOs showing all the signs of aircraft scatter — a sudden appearance of a signal, reasonable signal strength, some flutter, then a gradual decrease in signal strength. Aircraft scatter is possible to about 500 miles, but 200 to 350 miles is near optimum.

While I haven't received any reports of activity, this band is a natural for 33-cm EME, since small-diameter (12 foot) dish antennas should be sufficient for such communications. The lack of EME operation on 33 cm is probably attributable to the fact that few, if any, Amateurs are using high power (greater than 150 watts) amplifiers on the band. I'm sure this QRP situation won't last very long!

As you know, I like to keep track of DX records on the frequencies above 50 MHz. At the present time the best DX reported on 33 cm is a mere 377 miles (606 km).[4] Let me know if you break this record. Once again, I believe this record will be broken before this column is in print. What a great challenge we have on a new band!

33-cm antennas

As pointed out in last year's column, 33 cm is a transitional band for antenna design. Consequently, the loop Yagi is the most popular antenna type; it's easy to construct and has proved fairly successful.

Reference 1 included a description of a 33-element loop Yagi design on a 12-foot boom. This particular design is

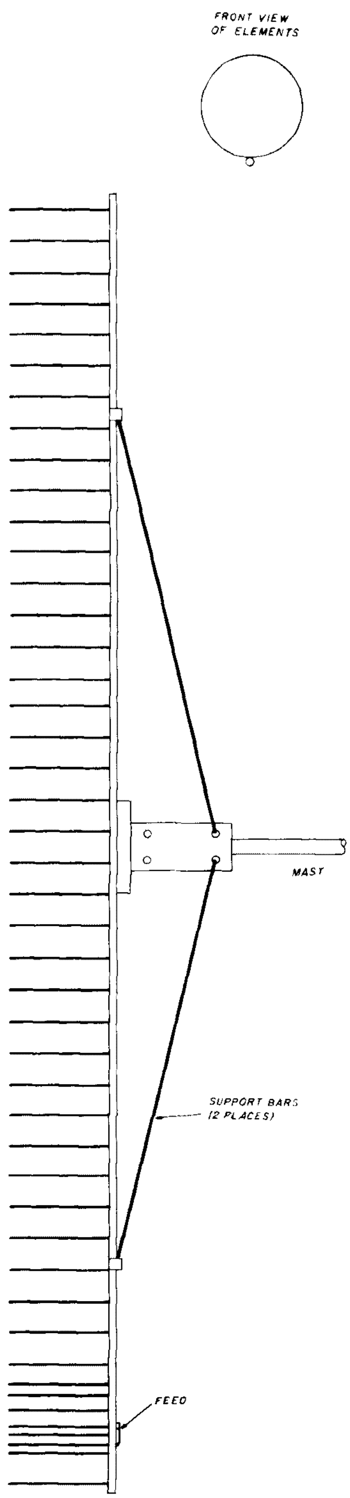


fig. 1. A recommended boom supporting scheme for a long boom loop Yagi antenna per reference 5.

probably not fully optimized, since it couldn't be scaled from any of the original designs shown in reference 5. However, it does have moderate gain (greater than 18 dBi) and a reasonably clean radiation pattern, as evidenced by the fact that most of the active 33-cm stations are using this or a similar design. Down East Microwave* sells a 33-element, 33-cm loop Yagi, but I don't know whether it's this or another design.

After a bit of head scratching on the subject of a simple approach for a higher gain antenna design, and a needle from Sam, W2PGC, I decided to build a 45-element loop Yagi scaled from the original 45-element, 23-cm optimized design described in reference 5. This would require a boom length of 17 feet, 2 inches.

After more thought about available materials and tubing sizes, I decided to use a 17-foot, 6-inch boom. The first part of the boom is the same length as the original design (12 feet) with the same diameter tubing (1 inch). A 6-foot length of 7/8-inch tubing is then inserted 6 inches into the director end of the boom for an overall length of 17 feet, 6 inches.

With this longer boom length and smaller diameter tubing on the front end, the overall strength of the boom will be decreased. A larger diameter boom could be used, but that would be more expensive and increase wind load, which is already high on a loop Yagi design. Therefore, I recommend a boom supporting structure similar to the one described in reference 5. A simplified sketch of it is shown in **fig. 1**.

Since there was a little extra boom available with a 5-foot, 6-inch extension, I added another director, making the new design one of 46, rather than 45, elements. The final design is shown in **fig. 2**; the driven element details are shown in **fig. 3**. This longer boom design uses the same element materials as the older 33-element design, with a slightly different element length taper schedule.

The gain of the 46-element loop Yagi should be about 20.5 dBi, a big improvement over the 33-element design. The beamwidth is approximately 15 and 16 degrees in the E and H planes, respectively. Therefore, the recommended stacking distances per references 5 and 6 are 37 and 35 inches in the E and H planes, respectively.

Finally, the original 33-element loop Yagi described in reference 1 was designed for 902 MHz. As a purist, I thought that the new longer boom model should be moved slightly higher in frequency. Hence the spacings and element lengths on the 46-element loop Yagi differ slightly from those on the original 33-element design.

If anyone wants to extend the original 33-element design, I don't think it will matter much if the old spacing is maintained. All that will be necessary is to add the extra boom section and directors, placing them each 5.115 inches further out from the preceding director. Don't forget to always reference element spacings from reflector No. 2 in order to keep any tolerance buildup to a minimum. Also note that some of the director lengths of the original design should be changed as shown in **fig. 2** if optimum performance is expected.

Several Amateurs are developing experimental long boom (12 feet or longer) Yagi designs, but they'll need to wrestle with the problems of boom corrections and impedance matching — a formidable problem on the UHF bands. I'll let you know how successful I am with mine!

Tonna Antennes (F9FT) has developed a short (8 foot, 4 inch) boom, 23-element Yagi. Marketed by The "PX" Shop,** it has a specified gain of 18.2 dBi with a 21- by 22-degree E and H plane beamwidth, respectively. Tonna Antennes circumvented the problem of boom corrections by mounting the elements above the boom on specially designed standoff insulators similar to those on their 23-cm designs. The feed system uses a folded dipole.

Needless to say, there will be some

*Down East Microwave (W3HQT), Box 1655A, RFD No. 1, Burnham, Maine 04922.
**The "PX" Shop (KC2PX), 52 Stonewyck Drive, Belle Meade, New Jersey 08502.

more churning going on in 33-cm antenna design in the forseeable future. Older designs will be improved and new designs will be forthcoming. Only time will tell whether the present antenna approaches are optimum for the 33-cm band.

circuit update

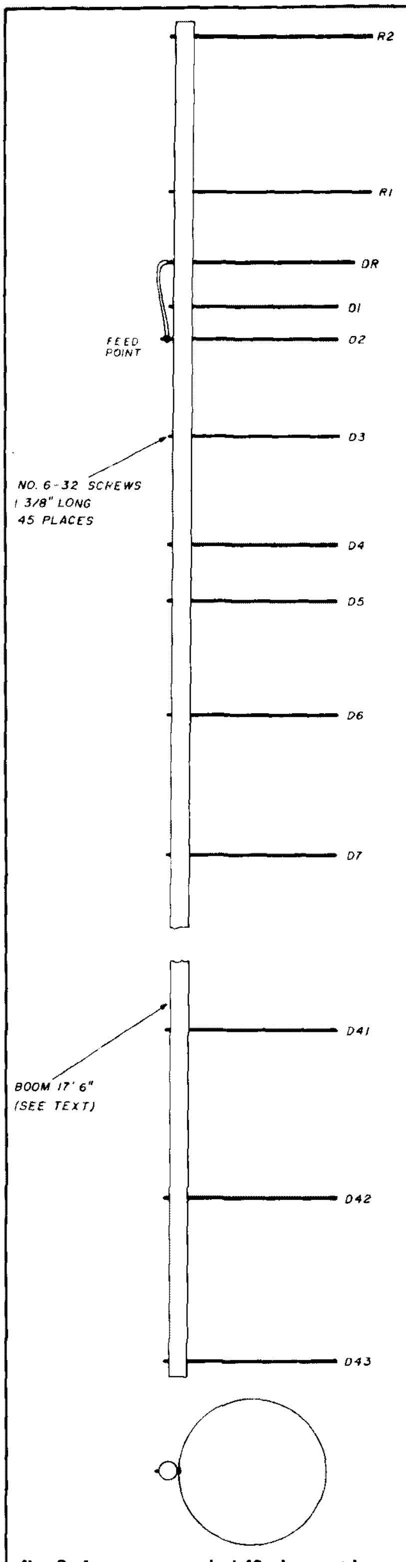
The converter/transverter designs in reference 1 have worked out quite well for many of us on the 33-cm band. Note that a few errors appeared in some of the figure captions in reference 1: the conversion loss of the transmit type upconverter shown in **fig. 3** should be 16 dB (not 9 dB), and the gain of the medium power amplifier in **fig. 12** should be 20 dB (not 30 dB).

Some additional comment on the hybrid modules are in order. Since reference 1 was published, the USA distributor for Toshiba has discontinued importing the SAU11 and SAU15 hybrid modules. However, I've been advised by Hiro Shiozawa, JA0JCJ, that he can provide some of the modules — particularly the Toshiba units — directly from Japan. I'd suggest that you write to him to make further arrangements.*

There are several other sources of suitable hybrid modules. The NEC MC-5809 driver module mentioned in reference 1 works just as well as the Toshiba SAU15 as a 100-milliwatt linear amplifier. Although I haven't tried it, the NEC MC-5843 shown in **fig. 12** of reference 1 should work as well as the Toshiba SAU11, albeit at a higher price.

Other substitutes for the high power module with 7 to 8 watts minimum output power (such as the NEC MC-5828, MC-5829, and MC-5842) are also available. Each has a different gain and output power. Of particular interest is the MC-5828, which sports an output power of 8 watts *minimum*, with only 1-milliwatt input power — all for $42.50 in single quantities! The NEC distributor in the USA is California Eastern Labs.**

Although I have no specific part numbers or additional information, I



Element	Spacing (Note 2)	Circumference (Note 3)
R2	1.00	13.963
R1	5.449	13.963
DR	6.813	13.328
D1	8.420	11.913
D2	9.611	11.913
D3	12.166	11.913
D4	13.721	11.913
D5	16.515	11.913
D6	19.830	11.913
D7	24.939	11.913
D8	30.049	11.913
D9	35.158	11.913
D10	40.268	11.913
D11	45.377	11.913
D12	50.468	11.552
D13	55.596	11.552
D14	60.705	11.552
D15	65.814	11.552
D16	70.924	11.552
D17	76.033	11.552
D18	81.142	11.191
D19	86.252	11.191
D20	91.361	11.191
D21	96.471	11.191
D22	101.580	11.191
D23	106.689	11.191
D24	111.799	11.046
D25	116.908	11.046
D26	122.017	11.046
D27	127.127	11.046
D28	132.236	11.046
D29	137.346	11.046
D30	142.455	11.046
D31	147.564	11.046
D32	152.674	11.046
D33	157.783	11.046
D34	162.892	11.046
D35	168.002	11.046
D36	173.111	10.902
D37	178.220	10.902
D38	183.330	10.902
D39	188.439	10.902
D40	193.549	10.902
D41	198.658	10.902
D42	203.767	10.902
D43	208.877	10.902

Notes:
1. Dimensional tolerances should be held to ± 0.013, with ± 0.04 inches maximum.
2. Reference all spacings from the rear of the boom to prevent tolerance buildup.
3. The circumference dimension shown is the distance between the holes in the loop. The overall loop length should be approximately 0.5 inches longer than shown to allow 0.25 inch overlap on each end of the loop. The loops are 0.375 inches wide, made from a 0.062 inches thick aluminum sheet. Any deviations in thickness or width must be compensated for per reference 5.

fig. 2. A recommended 46-element loop Yagi designed for 903 MHz. Construction is similar to that described in references 1 and 5.

*Hiro Shiozawa, JA0JCJ, 1462 Osato, Kofu, 400 Japan.
**California Eastern Labs, 3260 Jay Street, Santa Clara, California 95054.

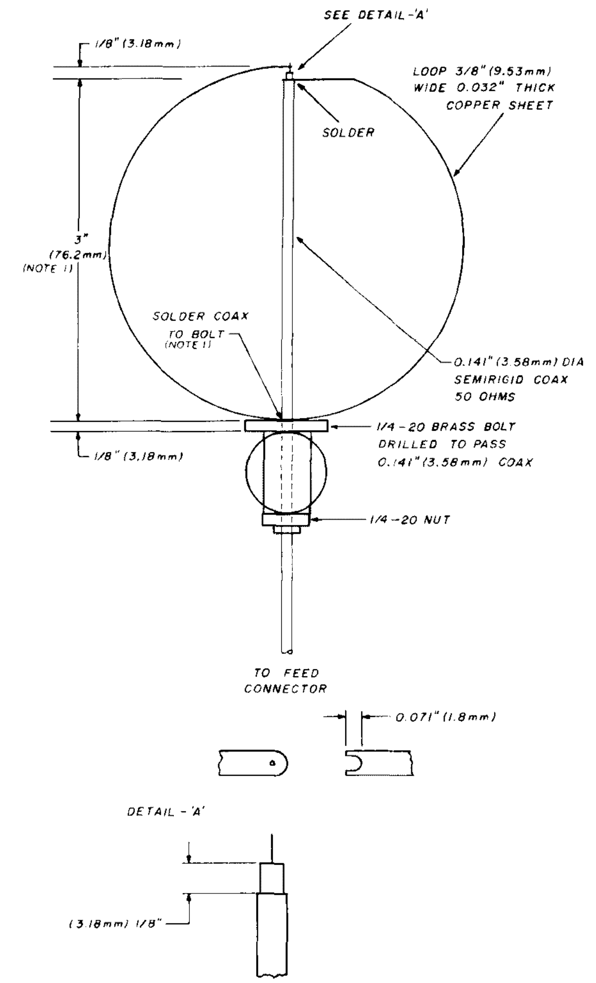


fig. 3. The feed system for the 46-element loop Yagi shown in *fig. 2.* Before soldering loop, adjust height (and length, if necessary) of loop for best VSWR.

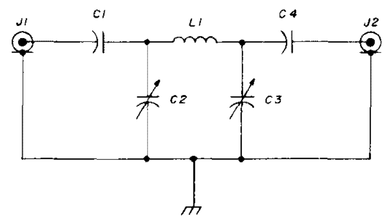


fig. 4. Schematic diagram of a low-loss, single-section bandpass filter. (See text for explanation of components. C1 and C4 are 0.5 pF; C2 and C3, 1-6 pF air variable. L1: 1 turn No. 14 AWG with a 0.25-inch inside diameter.)

know that Motorola also has a line of 33-cm hybrid power modules. The power levels are in the same class as the ones already mentioned, so if you're interested in using this type of module, I'd suggest that you also check the Motorola product line.

SSB with class-C amplifiers

The hybrid modules just described all operate in class C. In the past I speculated that you could run SSB through a class C amplifier with an acceptable IMD if certain parameters were taken into consideration. This is particularly advantageous when using solid-state "bricks" or hybrid modules, because previous attempts to rework them for class B bias usually resulted in thermal runaway.[7]

Since then I've verified with on-the-air tests that this is indeed possible. Basically the trick I use is to rf-bias rather than dc-bias the class C module by applying a small amount of carrier to an SSB signal. The optimum seems to be about 1 watt of output from the 10-watt class C module with no modulation applied.

I have an older phasing type of SSB exciter, so I just unbalance the carrier until the output of the module is about 1 watt without modulation. I then operate SSB normally. This procedure will probably work with other class C circuits and devices if the rf bias is held to about 10 percent of the maximum output power. One precaution: don't transmit on SSB using this technique for long periods of time unless you have an adequate heat sink attached to the hybrid module. You could destroy it!

transverters

The circuits described in reference 1 can be easily assembled for transverter operation with a common local oscillator and power splitter as described. As proposed, the modular approach allows quick insertion of new or improved designs as they become available. This approach has worked out well for homebrewers like me.

Recently SSB Electronics introduced the model LT33S transverter. Available from Transverters Unlimited,* it operates at 903 MHz with a 144-MHz i-f and sports a low-noise GaAsFET preamplifier and 6 to 10 watts of transmitter output power. This particular unit is quite popular with 33-cm enthusiasts.

linear amplifiers

As suggested in reference 1, there are many choices of bipolar power transistors for solid-state linear power up to about 20 watts. Unfortunately, time and space won't permit me to discuss new solid-state linears too deeply at this time, but I will make a few suggestions.

*Transverters Unlimited (VE3CRU), Box 6286 Station A, Toronto, Ontario, Canada M5W 1P3.

The NEC NE0804 (5 watts), the NE0810 (11 watts), and the Thompson-CSF (formerly Solid State Microwave) SD1418 common emitter power transistors are recommended. They should work well using a circuit similar to that used on 23 cm by WB5LUA.[8] All that's required for 33-cm operation is to lengthen the input and output lines and possibly change the value of the chip capacitor that shunts the base and collector of the transistor to ground.

Some medium power (40 to 100 watt) solid-state amplifiers are now being used. Typically they run class C with grounded base transistors. WA3JUF has proposed such a circuit using the Thompson CSF SD1414.[9]

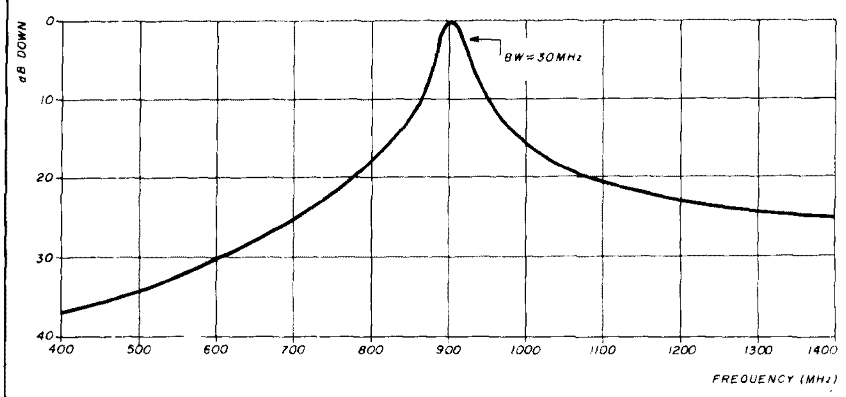


fig. 5. Passband plot of the bandpass filter shown in *fig. 4*.

high power amplifiers

For high power, tubes are strongly recommended. For power levels up to 100 watts, the ubiquitous 2C39/7289 is highly recommended. These tubes are plentiful and inexpensive.

W1RIL and others have modified the 70-cm 2C39/YD1050 amplifier described in *The UHF Compendium* to work on 33 cm.[10] They shortened the half-wave plate line to 78 mm (as opposed to 175 mm), shortened the output coupling link, modified the input matching network as required, and obtained 50 to 100 watts output with reasonable gain.

A 3CU400/800 flat cavity amplifier design is recommended for medium power levels (300 to 500 watts).[11] Quarter- and half-wave cavity amplifiers using the 7650/7651 or the larger 7213/7214 tubes are highly recommended. They work well on these frequencies, can deliver high power, and are often seen at flea markets. I'm sure that many surplus or UHF TV "pulls" are also available. Stripline amplifiers will probably still work adequately at these frequencies.

filters

The filters shown in reference 1 work well. However, they are entry level filters with fairly wide bandwidth. The input filter is particularly wideband but more than sufficient to protect the input of the MRF901 preamplifier design (shown in reference 1) if there are no local high power rf emitters such as UHF TV stations nearby.

Recently I developed an improved input filter with narrower half-power bandwidth — 30 versus 100 MHz — and less than 0.5 dB insertion loss. In addition, the 20-dB down points are only 300 MHz apart, as contrasted with the earlier design of 1000 MHz. It's similar to the design approach used in my 2-meter high dynamic range converter.[12]

A schematic of this single-section filter is shown in **fig 4**. C1 and C4 can be realized by connecting two 1.0-pF capacitors in series. C2 and C3 should be the piston or air-variable type if minimum insertion loss is desired. For lowest loss and best isolation, this filter should be built in its own shielded box (such as a Pomona Electronics 2417, 2428, or equivalent).

This filter is best tuned by adjusting C2 and C3 for minimum VSWR using a low power signal source. These capacitors will interact with each other, so alternate tuning until the VSWR is at a minimum. A typical passband plot of this filter is shown in **fig. 5**.

Likewise, the two-section bandpass filter shown in reference 1 is also an entry level filter. It has a half-power bandwidth of 50 MHz, which is a little too wide if a 28-MHz i-f is used. A slightly more complex three-section filter with a narrower half-power bandwidth, 36 MHz, and better skirt selectivity of 100 MHz, rather than 350 MHz (30-dB down points), has been developed. A schematic is shown in **fig. 6**.

This filter is of the combline type with the input and output connections made directly to the resonators. The coupling is set by the spacing between resonators, the height of the filter enclosure, and the input/output tap position.

As with the single-section filter just described, the tuning capacitors should be of the low-loss piston or air-variable type. The resonators should be spaced 1 inch center-to-center and mounted midway between the top and bottom of the enclosure. The filter is built in a small shielded box (with 4 x 2 x 1-inch outside dimensions) such as the Hammond 1590L or equivalent. The most important parameter of the shielded box is the height inside the enclosure, which is about 0.8 inches. This filter can be tuned for minimum loss, but for best performance a sweep-tuned setup is required. A typical passband plot is shown in **fig. 7**.

preamplifiers

The MRF901 preamplifier in reference 1 has performed quite well. Until recently it has been my only preamplifier. Though its noise figure is too high (typically 3 dB) for serious weak-signal operation it makes an excellent second-stage postamplifier.

For a really low noise figure, use a GaAsFET preamplifier. I've recently

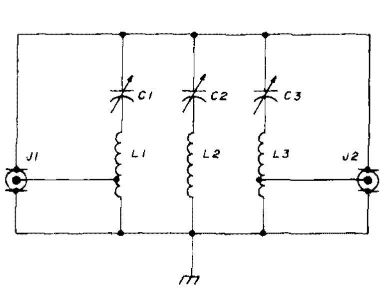


fig. 6. Schematic diagram of a three-section bandpass filter for 903 MHz. (See text for details on components and tuning. C1, C2, C3: 1-6 pF air variables. J1, J2: input/output connectors (type BNC or equivalent. L1, L2, L3: 0.25-inch wide thin (0.02-0.03 inch) copper strap spaced 1.0 inch center-to-center in a shielded enclosure, per text. Tap L1 and L3 0.25 inches from the grounded end of the inductor.)

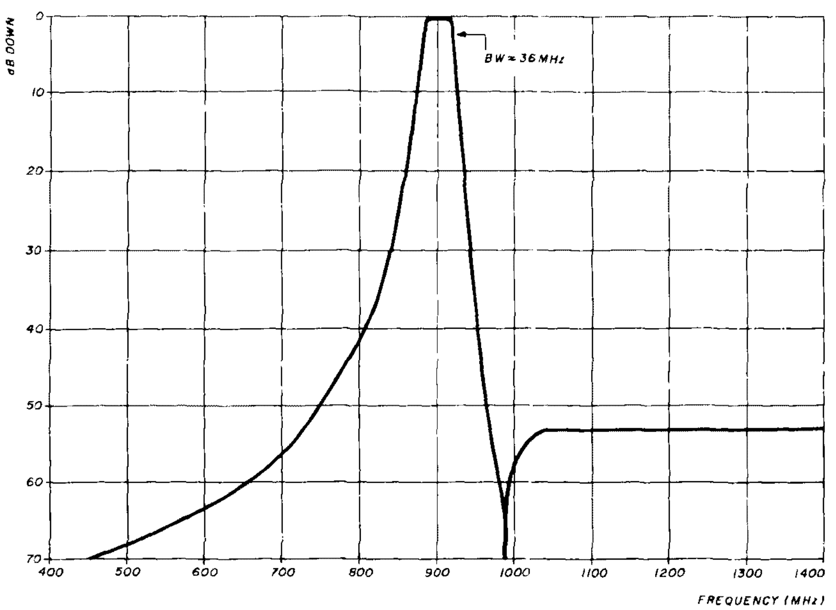


fig. 7. Passband plot of the three-section bandpass filter shown in *fig. 6*.

built one similar to the design shown in reference 13. A schematic is provided in **fig. 8**. The input circuit, a tuned tank, is easy to construct and provides a reasonable amount of selectivity, reducing the susceptibility to overload from high power emitters in the VHF range and below.

The output matching circuit uses a 4:1 L-network transformer that worked well for me on the VHF bands and is relatively broadband with low loss. As a result, the output compression point is very high; this is a performance parameter some of the other matching schemes I've used didn't have.

To align the preamplifier properly, a good noise figure generator is recommended. However, adequate performance can be obtained by using a weak-signal source for tuning. After tuning C1 and C2 for best sensitivity, spread or compress the turns on L2 for maximum gain, typically 13 to 15 dB. Overall noise figure is a function of the construction and GaAsFET used, but 0.5 to 1 dB is typical. The device type isn't critical; the MGF1402, MGF1301, NE72019, or equivalent GaAsFETs should all work well.

receivers

Wide-frequency coverage receivers (such as Yaesu's FRG9600) are now available. *Not* necessarily weak-signal types, they have noise figures typically in the 6 to 10 dB range; a low-noise preamplifier ahead of the receiver is recommended for weak-signal operation. The new ICOM R-7000, designed to cover from 25 to 1000 MHz and from 1030 to above 1300 MHz, offers excellent frequency stability and weak-signal characteristics on the 33- and 23-cm bands.

commercial fm gear

As mentioned in reference 1, a portion of the 33-cm band is a citizens band in Japan. As a result, many low power (5 watt) fm transceivers are available in Japan, but not yet in the USA, although that situation could change any day now.

Table 1 shows a few of these transceivers. They're all citizens band type with typically 75 to 100 fixed channels between 903 and 905 MHz. These transceivers have F3E emission and a nominal 5 watts output power. They're very small and excellent for portable operation.

One channel on these transceivers is at 903.1125 MHz. W1XX and others have been using this channel at portable locations because it's close to the weak-signal calling frequency. However, if these transceivers become available in the USA, I hope that they'll be used only above 904 MHz so as not to interfere with weak-signal operations near 903.1 MHz.

summary

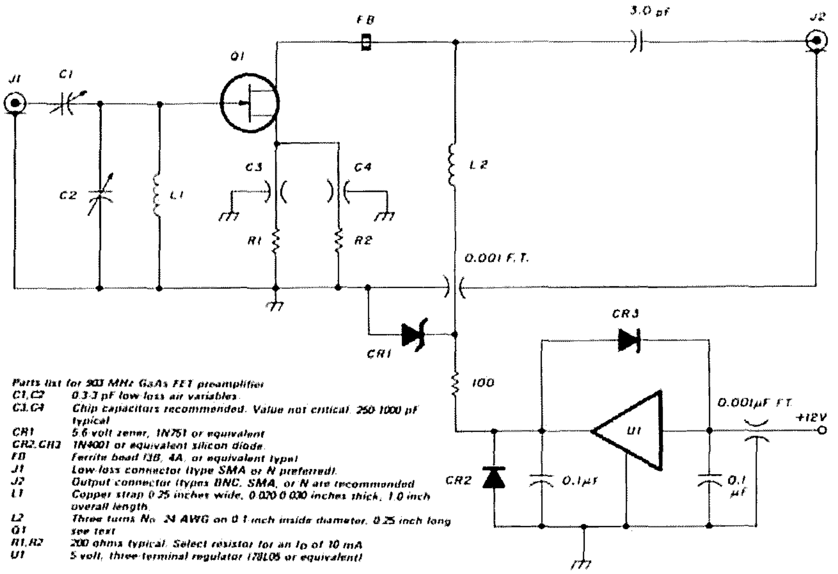
This month's column reviewed the current status of operation on the 33-cm band. New higher performance circuits and some equipment, both homebrewed and commercial, were recommended. Improvements to the circuits recommended in reference 1 were also discussed. I hope this information will stimulate increased activity. . . see you on 903.1 MHz, especially on Friday evenings — a recommended activity night — at 9 PM (local time)!

acknowledgments

I'd like to thank Bart Jahnke, KB9NM, of the ARRL for his help in locating the information on the Japanese fm citizens band gear.

SMIRK lives

Ray Clark, K5ZMS, president of SMIRK (Six Meter International Radio Klub) has recently informed me that



Parts list for 903 MHz GaAs FET preamplifier

C1,C2	0.3-3 pF low-loss air variables.
C3,C4	Chip capacitors recommended. Value not critical. 250-1000 pF typical
CR1	5.6-volt zener, 1N751 or equivalent
CR2,CR3	1N4001 or equivalent silicon diode.
FB	Ferrite bead (3B, 4A, or equivalent type)
J1	Low-loss connector (type SMA or N preferred).
J2	Output connector (types BNC, SMA, or N are recommended
L1	Copper strap 0.25 inches wide, 0.020-0.030 inches thick, 1.0 inch overall length.
L2	Three turns No. 24 AWG on 0.1-inch inside diameter, 0.25 inch long
Q1	see text
R1,R2	200 ohms typical. Select resistor for an Id of 10 mA
U1	5 volt, three-terminal regulator (78L05 or equivalent)

fig. 8. Schematic diagram of a recommended 903-MHz GaAsFET preamplifier.

"SMIRK is still alive and kicking." However, because of budgetary constraints, copies of the quarterly newsletter won't be sent to anyone who isn't a paid-up member. If you're a SMIRK member and haven't renewed your dues, send $3 to Ray at his callbook QTH.

new award program

In order to stimulate more weak-signal operation on 70 cm (432 MHz), Art Holmes, WA2TIF, has instituted a new awards program. Basically, there's a monthly award for making at least 50 QSOs, a monthly award for 1000 points by multiplying number of QSOs times grids worked, and an endorseable award for working 100 or more different stations on the band. The only stipulation is that contacts made on nets and during contests don't count. Write Art at 11 Kerr Road, Rhinebeck, New York 12572, for further information.

new records

There have been some unusually late and long DX tropo openings this year. The one during the U.S.A. Thanksgiving weekend will be long remembered because so many North American records were broken. Although this represents preliminary information, I'll list those new records that I've been able to document.

The 70-cm tropo record is now held by Ray, WB3CZG, FN10AX, for a QSO on November 29, 1986, with Kent, WA5VJB, EM12LQ, of approximately 1318 miles (2120 km). On the same date, a new 23-cm record of approximately 1287 miles (2070 km) was set between Ray, WB3CZG, FN10AX, and Dave, KD5RO, EM13PA. Finally on November 28 and 29, 1986, the 13-cm (2304 MHz) record was broken several times by WB5LUA, KD5RO, K9HMB, and W8YIO. When it was all over, Dave, KD5RO, EM13PA, and Lew, W8YIO, EN82BE, emerged as the new record holders for a distance of approximately 940 miles (1516 km).

Just before this great weekend, Tony, K5PJR, EM26OP, and Jim, WA5ICW/5, EM04HX, set a new 6-cm (5760 MHz) tropo record of approximately 285 miles (459 km). November certainly was an exciting month for UHF and microwave records! Congratulations should go not only to the new record holders, but to all those who — if only for a few minutes — held the record. Great going! Keep it up!

grid square index

Recently Folke Rosvall, SM5AGM, created *The Radio Amateur's World Atlas*, a 24-page book of maps and tables which show the geographical coordinates of all 32,400 grid squares in the world, along with an extensive index of cities worldwide. I've been using this book for some time and find it quite helpful in locating grid squares of stations in the USA as well as DX stations anywhere in the world. Since most of my acquaintances seem to be unaware of this book, I thought I'd mention it because it's so helpful with my record keeping. It's available from Ham Radio's Bookstore for $3.95 plus $3.50 shipping and handling.

references

1. Joe Reisert, W1JR, "VHF/UHF World: 33 cm — Our Newest Band," *ham radio*, April, 1986, page 83.
2. Joe Reisert, W1JR., "VHF/UHF World: Microwave and Millimeter-wave Propagation — Part 1," *ham radio*, July, 1986, page 82.
3. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-wave Propagation — Part 2," *ham radio*, August, 1986, page 69.
4. Joe Reisert, W1JR, "VHF/UHF World: The Ubiquitous Diode — Part 1," *ham radio*, February, 1987, page 51.
5. Joe Reisert, W1JR, "VHF/UHF World: Designing and Building Loop Yagis," *ham radio*, September, 1985, page 56.
6. Joe Reisert, W1JR, "VHF/UHF World: Stacking Antennas — Part 1," *ham radio* April, 1985, page 129.
7. Joe Reisert, W1JR, "VHF/UHF World: Medium Power Amplifiers," *ham radio*, August, 1985, page 39.
8. Al Ward, WB5LUA, "1296-MHz Solid-State Power Amplifiers," *QST*, December, 1985, page 41.
9. Dave Mascaro, WA3JUF, "33-cm Circuits," *Mid-Atlantic States VHF Conference*, October 4, 1986.
10. K. Winer, DJ9HO, *The UHF Compendium: Part 1 and 2*, January, 1982, page 272 (out of print).
11. Robert I. Sutherland, W6PO, and William I. Orr, W6SAI, "A High-Power Cavity Amplifier for the New 900-MHz Band," *QST*, November, 1982, page 14.
12. Joe Reisert, W1JR, "VHF/UHF World: High Dynamic Range on 2 Meters," *ham radio*, November, 1985, page 54.
13. Joe Reisert, W1JR, "VHF/UHF World: Low-Noise GaAsFET Technology," *ham radio*, December, 1984, page 99.

Important VHF/UHF Events

April 13:	*ARRL 144-MHz Spring Sprint Contest (evening)*
April 18:	*EME perigee*
April 21:	*ARRL 220-MHz Spring Sprint Contest (evening)*
April 22:	*Predicted peak of the Lyrids meteor shower at 1100 UTC*
April 24-26:	*Dayton HamVention*
April 29:	*ARRL 432-MHz Spring Sprint Contest (evening)*
May 2-3:	*West Coast VHF Conference (contact WB6GFJ)*
May 5:	*Predicted peak of the Eta Aquarids meteor shower at 1300 UTC*
May 8:	*ARRL 902-MHz Spring Sprint Contest (evening)*
May 14:	*ARRL 1296-MHz Spring Sprint Contest (evening)*
May 15:	*EME perigee*
May 15-17:	*13th Annual Eastern VHF/UHF Conference, Nashua, New Hampshire (contact W1EJ)*
May 23-24:	*ARRL 50-MHz Spring Sprint Contest (evenings)*

ham radio

understanding noise figure

See why optimized NF doesn't imply best output S/N

Noise figure is probably the most common parameter used to specify the noise performance of amplifiers and other systems where noise performance is a critical feature. However, the concept of noise figure is often misunderstood, and quite often misapplied.

This can result in a system with noise performance far less than ideal. For example, it might seem that an improvement in noise figure of a low-noise system would naturally result in lower total output noise and better output signal-to-noise ratio. However, this isn't always the case. It's quite easy to improve the noise figure to its optimum minimum value while causing an *increase* in output noise and a degradation in signal-to-noise ratio for any given signal. John Maxwell gives a good review of this problem in reference 1.

Noise figure is a "figure-of-merit" (a measure of "idealness") that demonstrates the amount of noise a system such as an amplifier adds to a signal-processing task such as amplification. If an amplifier were perfectly noiseless, it would add no additional noise and the noise figure would be zero. Similarly, a noise figure of 3 dB implies that the amplifier adds as much noise to the system as was initially present prior to amplifying (remember, a 3-dB increase in power is a doubling in power.) Also, the noise figure is a measure of the amplifier's performance, not the circuit performance. That's why we may take a specific circuit and optimize the noise figure but actually degrade the output signal-to-noise ratio.

Noise figure, NF, is defined as 10 times the common logarithm of the "Noise Factor," F , and the noise factor is defined as the ratio of the total output noise power of a system (an amplifier, for example) to the output noise power due to the source alone.[2]

$$F = \frac{\text{Total output noise power}}{\text{Output noise power due to the source alone}} \tag{1}$$

$$NF = 10 \log F \tag{2}$$

The noise factor in **eqn. 1** is a ratio of the actual output noise of a system to the output noise that would be present due to the source alone if the system were perfectly noiseless. Two things are important to notice about **eqn. 1**: the first is that the noise factor is defined in terms of noise powers, and second is that it is defined at the output of the system. Examining **eqns. 1** and **2**, something is conspicuous by its absence — a signal. The noise figure apparently has no relation to any signal or to the S/N. In fact, you don't even need a signal to find the noise figure, and without a signal, you have an S/N of zero! Well, the noise factor (and noise figure in turn) may be loosely considered a noise-to-signal ratio where the source noise is both the signal and a component of the total noise.

However, the noise figure may be related to the S/N relatively simply. Consider an amplifier with the following parameters.

Michael E. Gruchalla, 2450 Alamo Avenue S.E., P.O. Box 9100, Albuquerque, New Mexico 87119

N_S = Source noise power delivered to the amplifier input

N_I = Amplifier equivalent input noise power

G_P = Amplifier power gain

P_S = Amplifier input signal power

Now, the numerator of **eqn. 1**, total output noise power, is actually the sum of the noise contributed by the amplifier and that contributed by the source. Also, a specific output power is given by the corresponding input power multiplied by the amplifier power gain. We can then write the noise factor as **eqn. 3**.

$$F = \frac{(N_S\,G_P + N_I\,G_P)}{N_S\,G_P} \tag{3}$$

Now, if we divide both the numerator and denominator by the output signal power ($P_S\,G_P$) and rearrange the terms, the results of **eqn. 4** are found.

$$F = \frac{P_S/N_S}{(P_S\,G_P)\;/\;[(N_S + N_I)\,G_P]} \tag{4}$$

In examining **eqn. 4**, we see that the numerator is simply the signal-to-noise ratio of the input source. Similarly, the denominator is the signal-to-noise ratio at the amplifier output. So the noise factor is equal to the input S/N divided by the output S/N.

$$F = \frac{S/N_{\,input}}{S/N_{\,output}} \tag{5}$$

This is commonly known as the "Friis Equation," in honor of H.T. Friis,[3] who originally developed it in 1944. A subtle but important point to observe about the Friis equation is that the term S/N input is the S/N of the *input signal, not the S/N at the amplifier input*. Also, it should be understood that this is *not* the definition of noise factor, but rather a derived expression computed from the definition given in **eqn. 1**.

optimum source resistance

For any amplifier system, a value of optimum source resistance exists which will produce an optimum minimum noise figure. The problem lies in the fact that the value of optimum source resistance is rarely even close to the resistance of the source we wish to use. The NF of the source-amplifier combination is then less than optimum. It is often thought that a resistor could be added in series or shunt with the source to modify its *apparent* value as seen by the amplifier to become the optimum source resistance. This would indeed improve the NF with respect to the apparent source resistance, but not with respect to the original source.

The addition of this resistor has two effects. First, it loads the source dissipating some of the signal power that would normally be available as amplifier input, causing the signal term of the S/N expression to be reduced. Second, it adds the resistor's thermal noise to the system, causing an increase in the noise term of the S/N. The net effect of adding the modifying resistor is that the output signal is reduced, and the output noise is increased, which results in an overall reduction in the S/N. However, the NF is reduced to its optimum minimum value! Is this contradictory? Can we truly improve the NF of a system **and** actually degrade the S/N? If this is true, is the NF a useful parameter at all?

Perhaps a practical example or two using the parameters of real components will clarify this problem. (For more detailed analyses, check references 1 through 4.) The basic difficulty lies in the fact that the addition of a series or shunt resistor to a given source resistance only modifies the apparent resistance of the source. The actual value remains unchanged. The source contributes a specific signal and a noise commensurate with its resistance. For some specific signal, this provides some source S/N. The modified source will exhibit a lower available signal for the same actual signal level due to the loading effect of the added modifying resistor. The thermal noise of the modified source may be higher or lower than the original source, depending on whether the added resistor was added in series or shunt. However, in all cases the source S/N for any given signal level of the original source will be reduced. The addition of a simple resistor to modify the source then in effect makes the source "more noisy," which in turn renders any noise of the amplifier system less significant. That can cause an improvement in the NF. However, since the signal has been made more noisy, the S/N is degraded.

examples

Consider the circuit shown in **fig. 1**. This is a classic model of a generalized amplifier showing the noise parameters.[4] The source E_{NS} is the RMS noise potential of the source resistor R_S. The amplifier noise is referred to the amplifier input as two *equivalent* input noise sources: an input noise potential E_{NI}, and an input noise current I_{NI}. If you check the specifications of various high-performance amplifiers, you'll find these parameters. It should also be emphasized that as with almost all noise parameters, the total noise available from the sources is a function of the noise bandwidth, BW_N, and the frequency of measurement. Generally, the spot noise values (noise per Hertz of bandwidth) are specified as a function of frequency.

In the model, the amplifier input resistance is R_I and the voltage gain is A_V. Both of these are defined as noiseless because all noise contributions are included in the two equivalent input noise sources. It can be shown that the optimum source resistance that yields the best NF is given by **eqn. 6.**[2]

$$R_S\ (optimum) = E_{NI}/I_{NI} \qquad (6)$$

With that optimum source resistance, the optimum NF is given by **eqn. 7.**[2]

$$NF\ (optimum) = 10\ log\left(1 + \frac{E_{NI} \cdot I_{NI}}{2kT}\right) \qquad (7)$$

where: k = *Boltzmann's constant* = $1.38x10^{-23}$ *watts-seconds/°k*
T = *Absolute temperature in °k*

As an example, consider the source as a magnetic phonograph cartridge with a source resistance of 1000 ohms and a noise bandwidth of 20 kHz. Also, consider an LF356 FET amplifier configured for a voltage gain of 100. The LF356 parameters from the data sheets are given below.

R_I = 10^{12} ohms
E_{NI} = 12 nV/Hz @ 1 kHz
I_{NI} = 0.01 pA/ Hz @ 1 kHz (shot noise of input current)
A_V = 100 (configured gain)

To simplify the example, the noise contributions of any circuit resistors are ignored. (If we were actually trying to optimize noise performance, those noises would be included.) Also, consider that the 1 kHz spot-noise values given are constant over the frequencies of interest. From **eqn. 6**, the optimum source resistance is found to be 1.2 megohms; from **eqn. 7**, the optimum NF at that source resistance is found to be 0.063 dB! This very low optimum NF is typical of FET-input devices, but the very high optimum R_S often results in poorer practical noise performance (S/N) than that provided by higher noise bipolar devices. This occurs because the optimum source resistance for typical bipolar elements is often much nearer the value of typical sources (such as our phonograph cartridge) than that of FET devices. This will be demonstrated below. The NF for this amplifier with the 1-k source is 9.9 dB. That is much poorer than the 0.063 dB optimum. The output noise is 179 μV RMS. (Note: noise signals must be added as powers or by adding their mean-square values.) Adding a 1,199,000-ohm resistor in series with the 1-k source provides an optimum 1.2-megohm source resistance to the amplifier. The output noise is then 2 mV RMS and the NF is indeed 0.063 dB. The optimum NF configuration will have an output noise eleven times higher than the less optimum unmatched case and in both cases the gain will be 100 (the 10^{12}-ohm amplifier input resistance does not load either source configuration significantly). Then, for any given signal, the optimum NF configuration will exhibit an output S/N eleven times poorer than the unmatched configuration. So, even though the NF is poorer for the unmatched case, the noise performance is better: 21 dB better!

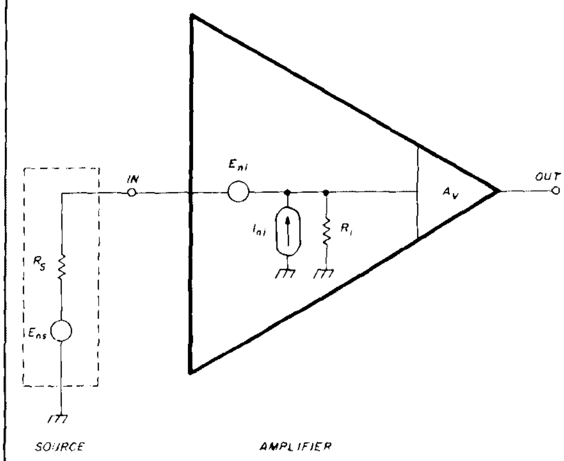


fig. 1. Amplifier noise model.

Now we'll try matching in a more optimum manner. Let the 1-k source be *transformed* to the optimum 1.2-megohm resistance with an ideal transformer having a 1:34.6 turns ratio. Note that this is not an optimum power match. We'll define the transformer as noiseless, but in a very accurate analysis its winding resistances would contribute some thermal noise that would have to be considered. Also, we'll adjust the amplifier gain to provide the same overall gain of 100 of the previous example to allow simple comparison. This does not affect the S/N or NF since both of these are independent of system gain and the transformer was defined as noiseless. Now the total output noise is 57.97 μV and the noise due to the source alone is 57.55 μV, resulting in the expected 0.063 dB NF. With the selected amplifier, this configuration will provide the best possible S/N for any given signal. It is 9.8 dB better than the simple unmatched case (20 log 170 μV/57.97 μV) and 30.8 dB better than the resistive matched case.

This may still be a little confusing, and you may be convinced that NF is a useless parameter. Let's examine what was done in the examples above. First we started with a device with a 1-k source resistance and an amplifier with a 1.2-megohm optimum source resistance and gain of 100. Direct application of the source to the *amplifier* gave us a signal gain of 100 with a 179 μV output noise and a 9.9 dB NF. Adding a 1,199,000-ohm series resistor gave us an optimum noise match with respect to the amplifier, with an out-

put noise of 2 mV and a 0.063 dB NF with the signal gain still 100. Since the gain was the same in both cases, the output signal would be the same for both for a given input signal. Then, since the output noise was higher in the second case than in the first, the S/N would be poorer, even though the NF was better.

What did we do wrong to get the lower NF case to give us a poorer noise performance? It's actually very simple. When we added the series resistance, the effective source seen by the amplifier was optimized, but the *actual* source resistance was unchanged. We inadvertently defined the source resistance in two different ways: as the real source resistance in one case and as the source plus a series resistance combination in the other. The 1-k source resistance is part of a circuit element that contributes both signal and noise. Adding a series resistance adds a circuit element that contributes only additional noise and no additional signal, so it should be expected that the S/N should be made poorer.

Looking back at **eqn. 1**, we see that the numerator is related to the source noise. If we define the source as the 1000-ohm resistance of our actual phonograph cartridge, we'll compute one value of output source noise, but if we use the 1.2-megohm resistance of the combined resistances, we'll find another (higher) value. As far as our amplifier is concerned, all components attached to its input constitute the source. However, to our actual source, only its elements constitute the source. When we add resistors to modify the source resistance, which value of source resistance should we use for the NF calculations? That depends upon what we're trying to find. If we wish to find the NF of an amplifier, everything tied to the input is then the source. If, however, we are trying to determine the NF of an amplifier with a specific source, only the actual source should be considered as the "source." In general, the actual source is the true source as far as the total circuit is concerned. Adding extraneous components to the source doesn't change its actual value, only its apparent value seen by the amplifier. Since it's the signal from a specific source that we're generally interested in processing, we should always compute the "output noise due to the source" in **eqn. 1** from the actual source of interest and not that "seen" by the amplifier input.

With this in mind, let's go back to our original phonograph cartridge source and LF356 amplifier. We found that the NF computed from **eqn. 2** with the source directly applied to the amplifier was 9.9 dB. When we added the 1,199,000-ohm resistor and defined the 1.2-Megohm source plus series resistance combination as the "source," we found an NF of 0.063 dB. Now, what would the NF be if we added the series *resistor* but still used the 1000-ohm value as the source resistance? It would be 30.9 dB! This clearly shows that with respect to our actual source, the addition of a series resistor only makes the NF poorer.

If we could *in some manner* make the actual source resistance and the source resistance seen by the amplifier equal the optimum source resistance, we would achieve the best possible noise performance. For example, if we could place in series 1200 of our phonograph cartridge sources (with each delivering the same signal), we would achieve the optimum source resistance with the actual source. That would provide the optimum NF and a very good S/N because the available signal power would be 1200 times that of a single source. However, that solution is obviously very impractical. We could possibly redesign the source to exhibit the 1.2 megohm resistance, but that too is generally impractical. The transformer offers us a very practical means of *transforming* the source resistance to the optimum needed, and well-designed transformers can do this almost noiselessly. With a transformer, both the signal level and source impedance are scaled together: potentials and currents by the turns ratio, and resistances by the turns ratio squared. This maintains the source S/N, as seen by the amplifier, constant. So, in our example, the entire equivalent 1.2-megohm source resistance at the transformer output contributes signal, 34.6 times more than the 1k-ohm source with a 1,199,000-ohm series resistor, with the same noise contribution of the optimum 1.2-megohm resistance. That obviously results in a much better S/N than the simple addition of a series resistor because the signal has been increased along with the increase in the source resistance seen by the amplifier.

In some applications we have control of the design of the source and can tailor its resistance to optimize noise performance with a specific amplifier. However, in the majority of cases the source resistance is fixed and we must select, or design, an amplifier whose optimum R_S is close to the specified source, or use a transformer to provide noise matching. For example, the LM1897 amplifier has an optimum NF of 1.82 dB at an optimum source resistance of 5.33 k. That optimum NF is much poorer than the 0.063-dB value of the LF356. However, this amplifier provides a 3.87-dB NF with the 1-k source resistance, which is much better than the 9.9-dB value provided by the lower noise LF356 with the 1-k source resistance. The higher noise amplifier, with the specified source resistance, will actually provide a 6-dB higher S/N than the lower noise unit for any given signal. This is because the LM1897 has an optimum source resistance value that more closely matches the 1-k source than the LF356. This shows that just because one amplifier has lower optimum noise figure than another, it may not provide better noise performance in a specific configuration or application.

Finally, there's the question of how the optimum NF source resistance relates to the optimum power match source resistance. That's very simple; they're totally unrelated. To demonstrate this, we can use a transformer to match the 1-k source resistance to the 10^{12}-ohm input resistance of the LF356, a turns ratio of 1:31,620. This will provide an optimum power match, but the NF will be 37.8 dB! That's considerably poorer than the 0.063 dB optimum NF provided at the optimum noise match. This is because the optimum noise source resistance is related to the equivalent input noise sources, and the optimum power match source resistance is related to the input resistance. In general, the equivalent input noise sources and the input resistance are unrelated, rendering the optimum matching resistances similarly unrelated.

The principal purpose in optimizing the power matching is to maximize power gain. In the case of optimizing noise performance, gain is not a particularly important consideration since additional gain stages may be added to obtain the total desired gain once the optimum noise performance is achieved. However, the process cannot be approached in reverse; you can't match for optimum gain and then optimize noise performance.

When using NF parameters specified for some specific device with which you are designing, you must carefully examine those specifications to be sure you understand what's presented. This is particularly true in the case of rf components. Quite often curves of optimum noise figure are presented showing the optimum NF as a function of frequency or bias current, but rarely is the actual value of the optimum source *impedance* given. Only at the optimum source impedance can the optimum NF be achieved. Since most rf measurements are made in systems of standard impedance such as 50 ohms, it might be assumed that the NF curves are given for that source impedance. If you make that assumption, you'll often find that you can't achieve the NF values specified. In other cases, only the NF curves at the measurement system impedance are given, providing no information for optimizing the source impedance for best NF. Even worse, you often can't tell from the provided information which source impedance was used. There are, of course, exceptions such as the NE388 series MESFET, but these are all too rare.

The situation is much better in the area of the lower frequency components. For those components, the "Contours of Constant Noise Figure" are quite often given. These show numerous curves of NF as a function of source resistance, operating point, frequency, etc. Using these data, one can quite effectively design low-noise audio, i-f and low-frequency rf amplifiers that provide the performance predicted by the mathematical design. In fact, performance somewhat

better than that specified for the part can often be achieved because the manufacturer must use conservative specifications to allow for a range of variation in the component line. In those cases where sufficient data isn't provided, you must make your own measurements of the various needed parameters. At lower frequencies that's relatively simple, but at the higher frequencies (i.e., greater than 100 MHz), that can be quite difficult without a collection of precision equipment.

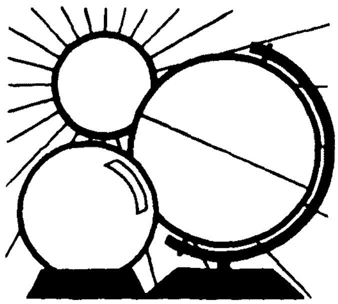
In conclusion, noise figure can be an excellent figure-of-merit for assessment of the potential noise performance of amplifiers and other systems, but a thorough understanding of the parameter is necessary if it's to be successfully applied. The performance suggested merely by the good noise figure of a device may not be reflected in the actual signal-to-noise ratio achieved from the device in a practical application. In an application where the source characteristics are predefined, it's generally more important to use an amplifier with an optimum source resistance that closely matches the specified source resistance than to merely choose an amplifier with the lowest possible noise figure. In no case can the signal-to-noise ratio of a system be improved by modifying the source resistance with a series or shunt resistor for making the combined resistance equal to the optimum source resistance for the system. This process can indeed result in the optimum noise figure with respect to the apparent source seen by the amplifier, but will always degrade the output signal-to-noise ratio for any given signal. If the "source" element used for determining the noise figure is always chosen as the actual source alone, meaningful results will be obtained.

It should be understood that the parameter noise figure is simply a figure-of-merit. In practical systems, it's the actual signal-to-noise ratio that's of primary interest. However, the optimum noise figure for an amplifier (or other system) does represent the best possible performance that can be achieved with that amplifier when the source resistance is properly matched to the optimum resistance for the amplifier. If you always compute noise figure using the actual physical source as the source referred to in **eqn. 1**, you'll always arrive at a correct result.

references

1. J. Maxwell, "The Noise Figure Fallacy," *National Transistor Data Book, National Semiconductor Corporation*, 2900 Semiconductor Drive, Santa Clara, CA 95051.
2. C.D. Motchenbacher and F.C. Fitchen, *Low Noise Electronic Design*, John Wiley and Sons, New York, 1973.
3. H.T. Friis, "Noise Figures of Radio Receivers," *Proceedings of the IRE*, July, 1944, pages 419-422.
4. R.D. Hudson, *Infrared System Engineering*, John Wiley and Sons, New York, 1969.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

a spring dx solution

Atmospheric noise from thunderstorms can be a problem when you're chasing DX during this time of the year. Noise is propagated via the ionosphere just like DX.

In March and April, spring storms occur in the northern hemisphere. Fronts of warm and cold air generate the first major thunderstorms of the year, with fast-moving cold fronts producing particularly potent thunderstorms. As a storm front approaches your area, you'll begin to hear a significant increase in the noise level. You'll first notice this increase at a one-hop distance (about 600 to 1200 miles) when the storm front is about one day west of your location. You can reduce the received noise a few dB by using a directional antenna such as a rotating Yagi or a phased vertical array. Determine the noise direction and work DX in the opposite direction, or do your best to null it out using a directional trade-off between signal and noise strengths. Antennas with a low take-off-angle (TOA) at the operating frequency are best because noise normally arrives at angles greater than 30 degrees.

As the front draws nearer, the noise level will usually decrease until it's within a ground-wave's distance (about 50 miles). Now, loud individual discharges will be heard. A horizontally polarized antenna is the best radiator to use to lower the noise as much as possible. As the storm approaches, its sounds become part of the "local noise"; as it moves away, its noise decreases, then increases again as the front reaches the one-hop distance point a day or so later. The directional-low TOA antenna again becomes helpful. (Correlate your observations with storm progress reports on the local television weather program.)

In looking for rare DX, you can save time by tracking storms in order to pinpoint when and where the most favorable listening conditions are likely to occur.

Over the years of gathering information for and writing this column, I've kept an ear open for data that would verify the events and propagation conditions presented in previous *last-minute forecasts* and *highest band available charts* in this column. To track the accuracy of these predictions, I plot daily values of solar flux and geomagnetic A (index) on a 27-day epoch graph and find it's hard to be right much over 60 percent of the time.

To verify published data, I monitor the ham bands and keep data collection in mind while DXing. What I usually look for is the highest band with signals, then note where they're coming from and the time the band is changing (out or in) towards that direction. During the month, I get a better sense of how good that month's chart was.

What do you think? Could the chart information be better? Let me know how you think it's working.

last-minute forecast

DX conditions on the higher frequency bands, 10-30 meters, are expected to be best through the first week and a half. The probability of transequatorial openings *should* be greater during this period of higher-than-normal solar flux, especially if geomagnetic disturbances materialize as expected on the down slope of this short-term flux peak. This month is still within the spring equinox disturbance window, so be aware and take advantage of this opportunity to work some southern stations.

The lower frequency bands will probably be affected by the disturbances expected around April 8-10 and 15-20. However, these will affect east, north, and west paths with lower MUFs and lower signal strengths with QSB. Look for DX from unusual locations if the disturbance isn't too strong — K's greater than 5 or 6. Otherwise, the second and third weeks should be good for DX, with low atmospheric noise except when spring weather frontal thunderstorms pass your QTH.

The perigee of the moon's orbit (for moonbounce DX) is on the 18th, with the moon showing full phase on the 14th. There will be a short meteor shower, the Lyrid, on April 20-22, with a rate of five per hour — hardly much help for meteor-scatter DX. But a bigger shower, the Aquarid, starts before the end of April, peaks on May 5, and ends in mid-May. Its rate is 10 to 30 per hour.

On March 29, expect a total eclipse of the sun in the southern part of South America and Antarctica, going up to Southeast Europe and Asia.

Ten, twelve and fifteen meters, the day-only DX bands, will be open midday to early evening almost every day to southern areas of the world. The openings on the higher of these bands will be shorter (if they occur at all), closer to local noon, and provide a possibility of transequatorial openings.

APRIL

WESTERN USA

GMT	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
PDT	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00
ASIA FAR EAST (N)	20	15	15	15	20*	20	20	20	20	*20*	*30*	*20*	20	20	20	20	20	20	*20*	*30*	*20*	20	20	20
EUROPE (NE)	30	*30*	*30*	*30*	30	20	20	*20*	*30*	*30*	20	20	20	20	15	15	15	15	15	15	20	20	20	20
S. AFRICA (E)	20	*20*	*20*	*20*	*30*	*20*	15	15	20	20	20	20	15	12	12	10	10	10	12	12	15	15	20	20
S. AMERICA (SE)	12	12	15	15	20	20	20	20	*20*	*20*	*30*	*20*	20	20	15	12	12	12	10	10	10	10	10	10
ANTARCTICA (S)	15	15	20	20	20	30	30	30	30	30	30	30	*40*	*40*	*40*	*40*	*40*	20	20	20	15	15	15	15
NEW ZEALAND (SW)	10	10	10	10	10	10	12	12	15	20*	20	20	*20*	*20*	*20*	*20*	*20*	20	15	12	12	10	10	10
OCEANIA AUSTRALIA (W)	10	10	10	10	10	10	10	12	20*	20	20	20	20	20	*20*	*30*	*30*	*30*	*30*	20	12	10	10	10
JAPAN (NW)	15	15	15	15	15	15	20	20	20	20	20	*30*	*30*	*30*	20	*30*	*30*	*30*	20	20	20	20	20	15

MID USA

MDT	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00
ASIA FAR EAST (N)	20	20	20	15	20*	20	20	*30*	*20*	*20*	20	20	20	20	20	20	20	20	*30*	*30*	*20*	20	20	20
EUROPE (NE)	20	*30*	*30*	*30*	20	20	*30*	*30*	*30*	20	20	20	20	20	15	15	15	15	15	20	20	20	20	20
S. AFRICA (E)	20	*20*	*20*	*20*	*30*	*20*	20	20	20	20	20	15	12	12	12	10	10	10	12	12	15	15	20	20
S. AMERICA (SE)	12	12	15	15	20	20	20	*20*	*20*	*30*	*20*	20	20	15	12	12	12	10	10	10	10	10	10	10
ANTARCTICA (S)	15	15	20	20	20	30	30	30	30	40	40	*40*	*40*	*40*	*40*	*40*	*40*	20	20	20	20	15	15	15
NEW ZEALAND (SW)	10	10	10	10	10	12	12	15	20	20	20	20	20	*20*	*20*	*20*	*20*	*20*	12	12	12	10	10	10
OCEANIA AUSTRALIA (W)	10	10	10	10	10	10	12	15	20	20	20	20	20	20	*30*	*30*	*30*	*30*	*30*	20	12	10	10	10
JAPAN (NW)	15	15	15	20	20	20	20	20	*30*	*30*	*30*	20	20	20	*30*	*30*	*30*	*30*	20	20	20	20	15	15
CDT	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00

EASTERN USA

EDT	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00
ASIA FAR EAST (N)	20	20	20	20	*20*	*20*	*20*	*20*	20	20	20	20*	15	15	20*	20	20	20	20	*30*	*30*	*30*	20	20
EUROPE (NE)	20	20	30	*30*	*30*	*30*	*30*	*30*	20	20	20	20	20	20	20*	15	15	15	15	20*	20	20	20	20
S. AFRICA (E)	20	*20*	*20*	*20*	*30*	*20*	20	20	20	20	15	12	12	12	10	10	10	10	12	12	15	15	20	20
CARIBBEAN S. AMERICA (SE)	12	12	15	20	20	20	20	*20*	*20*	*30*	*20*	20	15	12	12	12	10	10	10	10	10	10	10	10
ANTARCTICA (S)	20	20	20	30	30	30	30	30	40	40	40	*40*	*40*	*40*	*40*	*40*	*40*	20	20	20	20	20	20	20
NEW ZEALAND (SW)	10	10	10	10	12	12	15	20*	20	20	20	20	20	*20*	*20*	*20*	*20*	20	15	12	10	10	10	10
OCEANIA AUSTRALIA (W)	10	10	10	10	12	12	15	20	20	20	20	20	20	20	*30*	*30*	*30*	*30*	*30*	15	12	10	10	10
JAPAN (NW)	15	15	20	20	20	20	20	*20*	*20*	20	20	20	20	20	*20*	*30*	*30*	*30*	20	20	20	20	15	15

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

Twenty, thirty, and forty meters are both day and night bands. Twenty meters is the maximum usable band for DX in the northern directions these days during the daytime; it then teams up with 30 meters to extend this coverage into evenings. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30.

Eighty and one-sixty meters, the night-only DX bands, will exhibit short-skip propagation during daylight hours, then lengthen for DX at dusk. These bands follow the darkness path, opening to the east just before your sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas during the hour or so before dawn. Eighty is the maximum usable band for some night hours now during the sunspot minimum part of the cycle; consequently, signal strength quality can be expected to improve. Remember the DX windows of 3790-3800, 1825-1830, and 1850-1855.

ham radio

product REVIEW

the DEO QSK-1500

When I was a Novice back in the 1960s, my club station had a Johnson Ranger I, a Hammarlund HQ-120, and a Johnson TR switch. I spent hours on the air and really enjoyed being able to work full break-in CW. I got spoiled in that first year of being a ham, not having to listen to the clunking of relays and switches.

Since then I've dreamed of operating break-in CW again. Until recently, however, I never had a fully QSK-compatible radio. When I finally acquired one of the new do-it-all-but-burp-the-baby radios, QSK was once again possible. But I couldn't operate high power QSK. What to do?

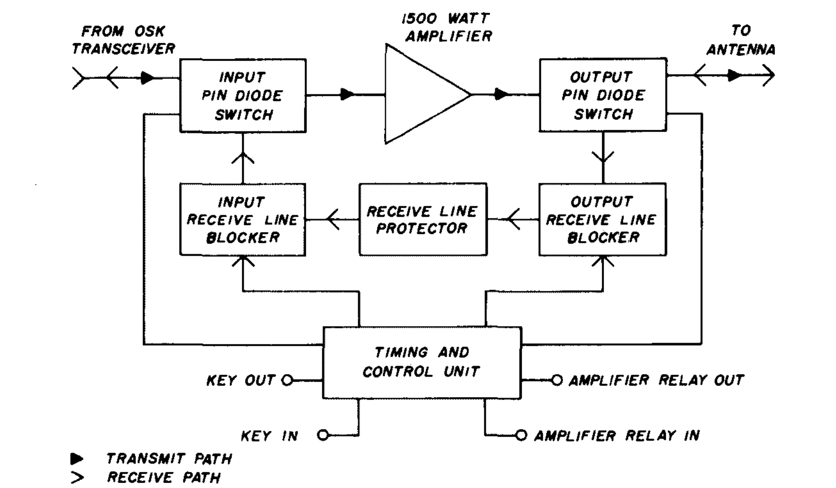


fig. 1. Block diagram of QSK-1500.

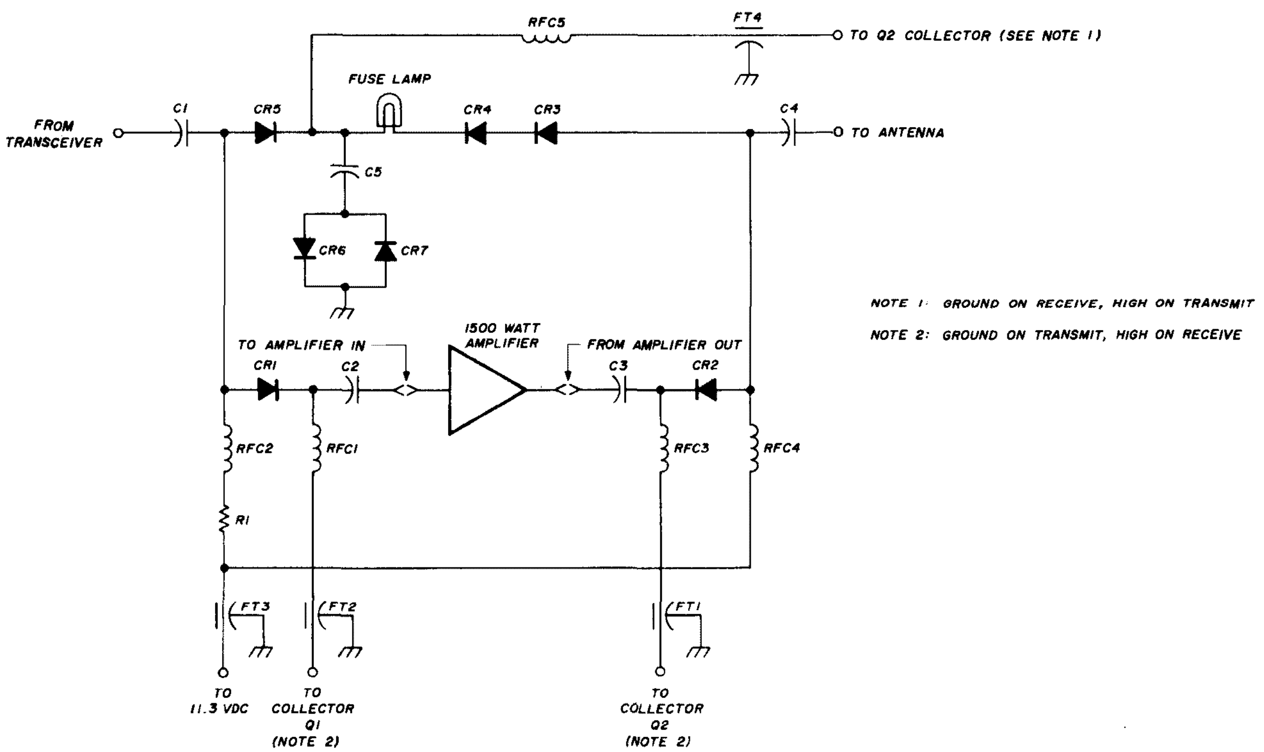


fig. 2. Schematic of RF switching section of QSK-1500.

QSK – what is it?

Basically stated, QSK is the ability to hear between the dots and dashes while transmitting a CW signal. A number of methods can be used to effect QSK operation: separate transmit and receive antennas, a vacuum tube TR switch such as the Johnson mentioned above, and expensive vacuum switches.

Each of these designs, however, presents a number of difficulties. Not everyone has a receiver with an AGC circuit capable of operating in the presence of a strong rf field without "folding up" or the space necessary for separate transmit and receive antennas. The TR switch had two significant problems: it created a tremendous amount of TVI and caused attenuation on the receive signal (commonly called "suck-out"). Vacuum switches require complex, precisely timed circuits to prevent "hot-switching" and aren't cheap to manufacture. Another problem was that some of these schemes introduced distortion onto the transmitted signal.

modern technology to the rescue

Several technological advances in the late 1960s brought QSK closer to reality for the average ham. Until the late 1970s, however, TEN-TEC was the only manufacturer to offer a QSK-compatible radio.

By 1980, transceiver manufacturing took a quantum leap forward and QSK-compatible radios were available from almost all radio manufacturers. Unfortunately, one problem remained; unless you owned either an Ehrhorn Alpha 77 or 78, you couldn't operate high-power QSK. Several after-market, add-on QSK units were introduced, but they suffered many of the same problems as other units.

In mid-1984, John ("Doc") Sheller, KN8Z, designed a solid-state QSK switch that solved many of the problems of earlier QSK units, using state-of-the-art PIN diodes as rf switches.

PIN stand for layer doping (P), intrinsic layer (I), pure and nd doping (N) layer. The thickness of the intrinsic layer determines the characteristics of the diode and allows the manufacturer to custom-design the diode for any of many different kinds of applications. A PIN diode is a solid-state device that acts like a variable resistor at rf frequencies. The amount of forward dc bias applied to the PIN diode determines the resistance (impedance) to rf signals. Doc's design is unique in that it has no moving parts — no relays — and can hot-switch high power rf. It needs only low dc voltage biasing to control rf currents, and by design, doesn't introduce any significant waveform distortion on the transmitted signal.

how it works

A block diagram and schematic (figs. 1 and 2) illustrate how the QSK-1500 works. The received signal travels from the antenna through the output line blocker, the receive line protector, and the input receive line blocker into the

front end of the transceiver. This circuit completely bypasses the conventional circuit path through the amplifier. The receiver is prevented from seeing the tank circuit of the amplifier by PIN diode CR2, which is reversed biased. PIN diodes CR3, 4, and 5 are forward biased and offer a very low impedance path for the receive signal. Typical insertion loss is less than 0.5 dB.

As you might expect, the transmit path is a little more complicated. Keying the transmitter triggers the timing circuit. The amp relay line is grounded, keying the amplifier. The input and output receive line blockers CR3, 4, and 5 are reverse biased with 525 volts dc; input and output PIN diodes CR1 and 2 are forward biased. The key-out line is closed and keys the transmitter. Rf flows from the transceiver through C1, CR1, and CR2 into the rf amplifier, it then flows through CR2, CR4, and C3 to the antenna. The reverse biasing of CR3, 4, and 5 prevents any rf from passing through the receive line. As soon as the morse character is completed, all the PIN diodes reverse state and the unit is back in a receive mode. PHEW!

So that's how this thing works. When you think about it, it's really quite simple. (For a more complete explanation of PIN diodes and how they work, see Doc's article on PIN diodes that appeared in the January, 1986, issue of *ham radio*.)

hookup and use

Setting up the QSK-1500 requires making four control cables. DEO recommends that you use RG-58 or other shielded cable to eliminate the possibility of rf getting into one of the units. Line 1 connects your key or keyer to the QSK-1500's timing circuit; line 2 connects your transceiver's amplifier control circuit to the timing circuit again. Line 3 connects the timing circuit back to the transceiver's keying line, and line 4 connects the timing circuit to the RF amplifier.

Rf connections are straightforward and can be followed by referring to **fig. 1**. Now you're ready to run a few tests. Turn your transceiver on. If everything is working correctly, you should hear nothing. This is because the receive line diodes aren't "on," so there's no receive path to your receiver. When you turn on the QSK-1500's power supply, the LEDs should light up; you should also hear signals. After a few more simple tests, you're ready to crank up the power and operate.

Once testing was complete, I was excited to see how QSK could actually be used. Tuning the low end of 160, I decided to look for a European or two; finding a fairly strong G3 calling CQ, I dropped my call in a couple of times, only to hear him start calling CQ again. I stopped calling immediately and waited for him to complete his CQ. Again I called, only to have him call another European. Stopping again, I realized how much QRM could be eliminated if more hams operated break-in CW — no more long-winded responses at 5 wpm while the DX station was calling again. QSO rates would increase dramatically, and many more of the "deserving" would get through.

The only problem I've had with this unit occurred one evening when I was working in the shack and had the radio on, but the QSK unit off. I dropped a hammer, tripping the radio's VOX. Later when I sat down to operate, I turned the rest of the equipment on, only to find that the receive line through the transmit antenna was dead! Since I could still receive through the Beverages (which bypass the QSK 1500 on receive), I ruled out the possibility of a radio problem. A quick call to DEO solved my problem immediately. Doc suggested I check the receive line fuse lamp; sure enough, it was blown. Inserting a new lamp cured the problem quickly and simply. Doc did advise me, however, to *always* make sure the QSK 1500 is turned on whenever the transceiver is. Without the fuse lamp, there's the possibility of damaging the PIN diodes, necessitating some fairly extensive repairs.

Doc reports that contesters who have QSK-1500 units have been pleased with the results; I'm anxiously awaiting the next contest to see for myself. I've had a lot of fun operating QSK. I expect the QSK-1500 is one review unit I'll use for quite awhile.

The QSK-1500 consists of a power supply and a control unit. The power supply measures 3 x 6 x 4 inches and the control unit 3 x 7 x 9 inches. One bit of warning: don't place the QSK-1500 on top of a radio, an amplifier, or any other heat-generating unit. The PIN diodes alone create plenty of heat in normal operation, and damage might result from improper placement.

Priced at $299 (plus $6 shipping and handling), the QSK-1500 is available from either Design Electronics of Ohio, 4925 S. Hamilton, Groveport, Ohio 43125, or from Universal Electronics, 1280 Aida Drive, Columbus, Ohio 43068.

— de N1ACH

NEW products

new ICOM catalog

ICOM America, Inc., has released its new 24-page, full product line color catalog. The new catalog includes all new products including the Micro 4AT 440-MHz handheld and the IC-275 all-mode VHF and IC-475 all-mode UHF base station.

For your copy, contact ICOM America, Inc., 2380 116th Avenue N.E., Bellevue, Washington 98004.

Circle #303 on Reader Service Card.

NEW products

computer rotor control interface

The most often requested new feature for satellite enthusiasts is automatic control of the antenna pointing via a personal computer. While the KENPRO KR0-5400A provides the electromechanical interface to the rotor motors, the actual hardware interface to the computer is provided by the KR-010. The KR-010 consists of analog-to-digital converters for both the elevation and azimuth channels and also provides the drive signal for driving the motors in the desired direction. An internal microcomputer provides the RS-232 serial capability at 9600 Baud without handshaking.

The KR-010 attaches to the serial port of the computer and operates with the tracking software (available only from the AMSAT software exchange, not from ENCOMM or KENPRO) written for AMSAT by W3IWI and W0SL. KENPRO and ENCOMM provide the software needed to point the antenna from data entered into a basic program in real time. Subroutines of the automatic tracking program which apply to the KR-010/KR-5400A combination and information on how to install them in the W0SL package is supplied with the KR-010.

The suggested retail price is $269.95. For details, contact Encomm, Inc., 1506 Capital, Piano, Texas 75074.

Circle #302 on Reader Service Card.

new from RF Concepts

Ken Holladay, K6HCP, and Everett Gracey, WA6CBA, the co-founders of Mirage Communications, have formed *RF Concepts*, a new company whose products include a state-of-the-art, all-mode 2-meter, 170-watt VHF amplifier with a GaAsFET receive pre-amp; a 450 MHz 100-watt UHF amplifier with a GaAsFET receive pre-amp; a 130-watt 220-225 MHz amplifier with a GaAsFET pre-amp; and a 30-watt HT amplifier, also with a GaAsFET receive pre-amp. Other products include a repeater amplifier for 440 MHz, 220 MHz, and 144 MHz and a full-function repeater controller.

On the drawing boards is a new dual-band amplifier, 144/440 and base station amplifiers, and state-of-the art switching power supplies from 10 to 35 amps.

For further information, contact RF Concepts, 2000 Humboldt Street, Reno, Nevada 89509

Circle #301 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

HOT/NEW PACKET PROGRAMS FOR YOUR IBM PC. Several telecommunications programs to choose from, especially written to interface your packet controller with your PC or compatible/clone. Features like Full Screen, Line Screen editing, Split Screens, ASCII, Binary, X-Modem or user defined file transfers, DOS shell, Macro Keys, Command Files, many types of time/date/oper. ID. Multi-page brochures explain them all. Software Support. Write for new information and pricing. KALT & ASSOCIATES, 2440 E. Tudor Rd, Suite 138, Anchorage, AK 99507. (907) 248-0133. Charge Cards accepted.

HOMEBREW PROJECTS LIST SASE. WB2EUF, Box 708, East Hampton, NY 11937.

FOR SALE: Tower, Rotator, Antenna Package – Tri-Ex W-67 Tower, motorized extension from 22' (nested) to 67' plus mast height. Hand winch operated tilt-over feature. CDE Ham III Rotator. Wilson DB-33 (10/15 meter beam). Cushcraft 20 meter beam. Very good condition. Package price $1250 firm. WA1USO, Fred Moller, Old Fitzwilliam Rd, Jaffrey, NH 03452. (603) 532-7635.

PERFORATED ENCLOSURES 17 x 8.5 x 7.5 deep with grey paint and 17 x 8.5 x 11 deep with iridite finish. Unpainted blank front panel. Approximately 50 each. $10 and $15 respectively. Quantity discount available. Don Reed, K0IFO, 911 North Lynn, Independence, MO 64050. (816) 252-9436

DISCOVER "THE RADIO WORKS". See what we are doing with high performance HF and VHF antennas, parts, and accessories. Unusual 48 page discount catalog. 22 cents SASE. The RADIO WORKS, HRAPR, Box 6159, Portsmouth, VA 23703 (804) 484-0140.

R-390A RECEIVER: $195 check; $115 reparable. Parts, tubes, sections. Info SASE. Mint military-spec pull-out 12AT7, 6AG5: $15/dozen. CPRC-26 six meter transceiver (see Ham Radio, March 1985) $17.50 apiece, $32.50 pair (add $4.50/unit shipping). Baytronics, Box 591, Sandusky, OH 44870. (419) 627-0460 evenings.

Foreign Subscription Agents for Ham Radio Magazine

Ham Radio Austria
Karin Ueber
Postfach 2454
D-7850 Loerrach
West Germany

Ham Radio Belgium
Stereohouse
Brusselsesteenweg 416
B-9218 Gent
Belgium

Ham Radio Holland
Postbus 413
NL-7800 Ar Emmen
Holland

Ham Radio Europe
Box 2084
S-194 02 Upplands Vasby
Sweden

Ham Radio France
SM Electronic
20 bis, Ave des Clarions
F-89000 Auxerre
France

Ham Radio Germany
Karin Ueber
Postfach 2454
D-7850 Loerrach
West Germany

Canada
Send orders to
Ham Radio Magazine
Greenville, NH 03048 USA
Prices in Canadian funds
1 yr $41.85, 2 yrs $74.25
3 yrs $99.90

Ham Radio Italy
Via Maniago 15
I-20134 Milano
Italy

Ham Radio Switzerland
Karin Ueber
Postfach 2454
D-7850 Loerrach
West Germany

Ham Radio England
c/o R.S.G.B.
Alma House
Cranborne Road
Potters Bar
Herts EN6 3JW
England

VHS VIDEO CASSETTES $29.50 total price for a box of 10 delivered anywhere in continental U.S. Call for 24-hour order information. KB6MT (714) 990-9622.

WANTED TO BUY zip code and directory published before 1980 publication No. 65. Bernard Fair, 19455 Houghton, Detroit, MI 48219.

S.S.B. CRYSTAL FILTERS. 9.0 MHz, 2.2 kHz bandwidth, six pole, with data $20.00 postpaid. OEM quantity available. ICL7117 D.V.M. I.C.'s direct drive 3-1/2 digit LED same as 7107 plus hold, with data; $6.00. 2/$10.00 postpaid. Dentron Scout C.A.P. transceiver, 4 MHz, 100 watts, new; $250.00. A.C.P.S. $75.00 postpaid. George Misic, 14481 Watt, Novelty, Ohio 44072.

1 Hz Resolution frequency synthesizer. For info SASE to A & A Engineering, 2521 W. LaPalma Avenue, #K, Anaheim, CA 92801. (714) 952-2114.

LEARN MORSE CODE IN 1 HOUR. Amazing new easy technique. Moneyback guarantee. $10. Bahr, 2549H Temple, Palmbay, FL 32905.

SUPERFAST MORSE CODE SUPEREASY. Subliminal cassette. Moneyback guarantee. $10. Bahr, 2549H Temple, Palmbay, FL 32905.

TEN-TEC now shipping new-boxed USA made latest 1987 factory models Corsair II, Century 22, Argosy II transceivers. Titan linear amplifier 229A 2kw antenna tuner plus accessories, antenna. For the best Ten-Tec deal write or phone Bill Slep (704) 524-7519, SLEP ELECTRONICS COMPANY, Highway 441, Otto, NC 28763.

WANTED Schematic for Bearcat 100 Electra, Model BC-100 Scanner. Please contact Ralph E. Smith, 857 Rougemont, St. Foy, Quebec City, Canada.

HEATH Deluxe antenna tuner Model SA2060 – a beauty – best offer. (401) 789-1817 FOB.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

COLLINS KWM-380. Fully updated. Excellent condition. Full service manual. Write or call. W3IRE, 9436 Howes Road, Dunkirk, MD 20754. (301) 257-3041.

BACK ISSUES OF HAM RADIO Magazine from March 1968 to June 1974. Complete your collection. Individual issues $4.00 each. KX9P (319) 377-3563.

IBM/APPLE COMPUTER program "Hamlog". 18 modules logs auto-sorts 7-band WAS/DXCC. Full feature. Also CP/M. Apple $19.95, IBM $24.95. HR-KA1AWH, PB 2015, Peabody, MA 01960.

LO COST Sensitive-Selective HF receiver system. Ideal/1st station set. Enhanced Novice 10/15/40/80m coverage. Send 2 stamps for free info. I. Megeff, KD2EF, 729 Lori Drive #101, Palm Springs, FL 33461.

HOBBY, EDUCATIONAL, INDUSTRIAL PRODUCTS. 70 kits. Amplifier, FM transistor, VU meter, door bell, alarm system, power supply. Send $3.00 to HOBBY ELECTRONIC, PO Box 1339, Claremont, NH 03743 or call (603) 543-0033.

COLLECTORS: Have Karl Pierson KP-81 communications receiver for sale. Complete system- receiver, speaker cabinet and book. Open to offers. Cal, KL7HEM, 10300 Silver Knolls, Reno, NV 89506.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

TRS80 4P/KANTRONICS UTU RTTY. Split-screen, 10 user keys, file transfer. Runs in Mod 4 (80 char) mode. $30 to COMMPRO RTTY, c/o KB6IC, 3711 Gayle Avenue, Omaha, NE 68123.

COMPUTERS COMMODORE 64 and XT repair. ABS (201) 758-6673.

CODE PROGRAMS. Apple/C-64. 31 modes, graphics, menus, wordprocessor, etc. LARESCO, POB 2018, 1200 Ring Road, Calumet City, IL 60409. (312) 891-3279.

SOLAR ELECTRIC PANELS and System Components. 1st quality for home or repeaters. Lowest prices in country. KA8DSS, RADIANT DISTRIBUTORS, 3900 Dursum, Ada, MI 49301. (616) 874-8899.

WA9GFR RF SOFTWARE $15.00 disk contains HF/VHF/UHF/L-BAND propagation and Smith Chart impedance matching programs. Specify Commodore-64 or MS-DOS BASIC. Lynn Gerig, 6417 Morgan RD, Monroeville, IN 46773.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photodocumentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

UHF PARTS. GaAs Fets, MMICs, trimmers, chip caps, teflon pcb, and other builder parts. SASE brings list. MICROWAVE COMPONENTS, 11216 Cape Cod, Taylor, MI 48180.

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

SHOW IT IN STYLE Full color QSL's by Smith Printing. From your prints/slides. Sample packet. SASE. 20420 Calhaven Drive, Saugus, CA 91350 (805) 251-7211.

WANTED: For Drake 4C the noise blanker 4NB (dead or alive). H. Schroefer, Dorfstr. 14, 3131 Gollau/Luechow, West Germany.

ANTIQUE RADIOS,
——— **schematics, tubes and literature. Send SASE to VRS (HR), 376 Cilley Rd, Manchester, NH 03103 for large list.**

HAM MONITOR SCOPE Millen 90932 $85, audio signal generator HP200-CD $125, Precision E-200-C AM/FM signal generator $45, Yaesu FRG-7 general coverage receiver $125, Johnson phone patch $25, trade for TR-9000. K6KZT, 2255 Alexander, Los Osos, CA 93402

YAESU OWNERS: Hundreds of modifications and improvements for your rig. Select the best from fourteen years of genuine top-rated Fox-Tango Newsletters by using our new 32-page Cumulative Index. Only $5 postpaid (cash or check) with $4 Rebate Certificate creditable toward Newsletter purchases. Includes famous Fox-Tango Filter and Accessories Lists. Milt Lowens, N4ML (Editor). Box 15944, W. Palm Beach, FL 33416. Telephone (305) 683-9587.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, New York 10538.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc., are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.

MICHIGAN: April 5. The South Eastern Michigan Amateur Radio Association's 29th annual Hamfest Swap and Shop, 8 AM to 3 PM, Grosse Pointe North High School, 707 Vernier Road, Gross Pointe Woods. ARRL, DX and Packet forums. Tickets $1.00 advance; $3.00 at the door. Tables $8.00 advance; $10.00 at the door. Talk in on SEMARA repeater 147.70/10 and 146.52 simplex. For information: SEMARA Hamfest, PO Box 646, St. Clair Shores, MI 48080 or phone Fred Lweis, NK8M (313) 881-0187.

MINNESOTA: April 4. 10th annual Rochester Area Hamfest sponsored by the Rochester ARC, John Adams Junior High School, 1525 NW 31st Street, Rochester. Doors open 8:30 AM. Large flea market, speakers, programs, refreshments and plenty of free parking. Talk in on 146.22/82. W0MXW. For further information contact: RARC c/o WB0YEE, 2253 Nordic Ct. NW, Rochester, MN 55901.

NEW JERSEY area Chaverim, an organization of Jewish Amateur radio operators completing its 4th successful year, invites all hams and those interested in Amateur Radio to join, particularly those in Monmouth and Ocean counties of NJ. We meet the first Sunday of the month in the Jewish Community Center, Grant Avenue, Deal. Write POB 192, West Long Branch, NJ 07764.

OHIO: April 24, 25, 26. DAYTON HAMVENTION.

The Dayton Amateur Radio Association is now accepting applications for its 1987 Scholarship Program. Any licensed Amateur graduating from high school in 1987 is eligible to enter. For information and application forms write DARA Scholarship Committee, 317 Ernst Avenue, Dayton, Ohio 45405.

OHIO: April 24. The 18th annual B*A*S*H* will be held on FRIDAY NIGHT of the Hamvention, at the Conference Center (Madison Room) of the HARA ARENA AND CONFERENCE CENTER, (the same location as the Hamvention) starting at 7:00 PM. There is no admission charge, and free continuous entertainment. Hot dinner, sandwichs, snacks and beverages are available. Two exciting top awards, and many others. Stay right at HARA when the Hamvention closes on Friday evening and meet your friends and join us for an evening of fun and entertainment. Sponsored by the Miami Valley FM Association, PO Box 263, Dayton, Ohio 45401

OHIO: April 24. The Dayton-Cincinnati Chapter 9 of the QCWA announces the 1987 QCWA Banquet, Friday night of the Dayton Hamvention. Neil's Heritage House in Dayton. COD bar at 6:30; dinner at 7:30. Tickets $13.00 each. Contact Bob Dingle, KA4LAU, 657 Dell Ridge Drive, Dayton, Ohio 45429. QCWA membership is not required to attend.

NEW JERSEY: May 9. The Cherryville Repeater Association's annual Hamfest, Hunterdon Central High School, Flemington. 8 AM to 4 PM. Indoor tables plus tailgating. FCC exams, forums displays and more. Talk in on 146.52, 147.975/.375. For further information or reservations call Bill Inkrote, K2NJ (201) 788-4080 or Don Mazak, NR2H (201) 782-1114.

COLORADO: June 20. The Grand Mesa Repeater Society will hold its 8th annual Western Slope Amateur Radio and Computer Swapfest, 9 AM to 4 PM, National Guard Armory, 482-28 Road, Grand Junction. Free admission. Swap tables $5.00 each. Indoor swapfest, Amateur Radio exams, auction and refreshments. Talk in on 146.22/.82 and 449.20. For tables or information SASE to Les Scott, NV0F, 2105 Yellowstone Rd, Grand Junction, CO 81503 or call (303) 242-5296.

CALIFORNIA: May 1, 2, and 3: The Fresno Amateur Radio Club will hold its 45th annual Hamfest, Fresno Airport Holiday Inn. Air conditioned dealer spaces and swap tables. FCC exams. Good programs and parking. Demonstrations and forums. Talk in on 146.34-94. For information: Glen T. Caine, Fresno ARC, PO Box 783, Fresno, CA 93712 or (209) 292-4611.

INDIANA: April 4. The 4th annual Columbus Amateur Radio Club Swapfest, Bartholomew County Fairgrounds in Columbus. 8 AM to 5 PM. FCC testing. Advance setup Friday, April 3 with overnite security provided. Free parking. Talk in on 146.790 and 444.950. For information: Dave Mann, KA9UUP, 458N Country Club Rd, Columbus, IN 47201 (812) 342-6302.

NEW YORK: May 3. The Suffolk County Radio Club's indoor/outdoor flea market, 8 AM to 2 PM, Republic Lodge No. 1987, 585 Broadhollow Road, Rt. 110, Melville, L.I. General admission $3.00. Spouse and kids under 12 free. Indoor tables $10. each. Outdoor spaces $7.00 each. Includes one free admission. Talk in on 144.61/145.21 and 146.52 simplex. For information: Bill Sullivan, N2ETG (516) 689-9871 evenings.

TENNESSEE: April 5. The Clarksville Amateur Transmitting Society is sponsoring their annual Swapfest, National Guard Armory, Hwy 41A, Clarksville. Tables $5.00 each. Free admission. Talk in on 146.52 or 146.805-.600 or packet 145.03. For tables or information call WD4DBJ, Larry, (615) 232-6141.

NEW JERSEY: May 3. The Tri-County Radio Association's annual Indoor Hamfest/Flea Market, Passaic Township Community Center, Stirling. 9 AM to 3 PM. Donations $3.00. Tables $8.00; w/power $10.00. Reserved tailgating. Refreshments. Talk in on 147.855/.255, 146.52 and 444.975/449.975. For information: Dick Franklin, W2EUF, POB 182, Westfield, NJ 07090. (201) 232-5955.

ARKANSAS: May 2. The Northwest Arkansas ARC will hold its 7th annual Hamfest, Rogers Youth Center, 315 West Olive Street, Rogers. 8 AM to 4 PM. Doors open 6 AM for exhibitors. General admission and parking free. Nearby recreational areas and parking for RV's and campers. Talk in on 16/76 or 03/63. For information: Roy Milliren, AF5W, 2014 S. 16th Street, Rogers, AR 72756 (501) 636-6750.

VIRGINIA: May 3. The Lynchburg ARC will hold its annual Swapfest, Brookville High School grounds, Route 460 West, just outside Lynchburg. Rain or shine. Starts 9 AM. Admission $1.00. Tailgaters pay general admission plus $2.00. VE exams beginning 1 PM. Please pre-register. For more information write Lynchburg ARC, PO Box 4242, Lynchburg, VA 24502.

OKLAHOMA: April 5. The Great Plains ARC's 6th annual Northwest Oklahoma Eyeball and Swapmeet, Mooreland, starting 9 AM. Admission $2.00. Dealer and swap tables available at no charge. Covered dish dinner at noon. Local airport. VE tests Saturday, April 4. Campsites available. Talk in on 147.72/12, 146.13/73 and 146.52 simplex. For information write Gerald Bowman, WG5Z, Box 356 Mooreland, OK 73852 or call (405) 994-5600.

MINNESOTA: April 4. The 10th annual Rochester Area Hamfest, sponsored by the Rochester ARC, John Adams Junior High School, 1525 NW 31st Street, Rochester. Doors open 8:30 AM. Admission $2.50 advance, $3.00 at the door. Spouse and harmonics free admission. Tables $8.00. Selling space $4.00, bring own tables. License exams. Walk-ins only. Talk in on 146.22/82, W0MXW. For information and advance tickets: RARC c/o WB0YEE, 2253 Nordic Ct NW, Rochester, MN 55901.

RHODE ISLAND: May 16. The RI Amateur FM Repeater Service will hold their annual Spring Flea Market and Auction, American Legion Fairmount Post 85, 870 River Street, Woonsocket. Flea market opens 9 AM and spaces are $5.00 each. Auction from noon to 5 PM. Free admission. Food and beverages available. Talk in on 34/94 and 52 simplex. For information: Rick Fairweather, K1KYI, Box 591, Harrisville, RI 02830 or call (401) 56;8-0566, 7-9 PM.

MASSACHUSETTS: April 25. The Montachusett ARA will hold a flea market, Knights of Columbus Hall, Electric Avenue. 9:30 to 3 PM. Doors open 8 AM for sellers. Admission $1.00. Tables $8.00. Refreshments available. Talk in on 144.85/145.45 and 52. For reservations send check payable to MARA, c/o James Beauregard, 7 Mountain Avenue, Fitchburg, MA 01420.

SOUTH CAROLINA: May 2 and 3. The Blue Ridge Amateur Radio Society's 48th annual Greenville Hamfest and Electronic Flea Market, American Legion Fairgrounds, Greenville. Saturday 8 AM to 5 PM. Sunday 8 AM to 3 PM. Admission $3.50 advance and $5.00 at gate. Indoor/outdoor flea market, license exams, free parking, food. For tickets or information SASE to Blue Ridge ARA, PO Box 6751, Greenville, SC 29606.

NEW HAMPSHIRE: May 9. New England's favorite – The Hosstraders Spring Tailgate Swapfest, Deerfield Fairgrounds. Admission $2.00 per person including sellers and commercial dealers. Friday night camping at nominal fee only after 4 PM. Profits benefit Shriners' Burns Hospital. Last year's gift over $13,500! For map. SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

PENNSYLVANIA: May 3. The Delaware County ARA is sponsoring their 8th annual Hamfest, Drexel Hill Middle School, State Road and Penn Avenue, Drexel Hill. Doors open 8 AM. Setup 7 AM. Admission $3. Reserved indoor tables/elec. available for $3.00 per space. License exams. Refreshments available. Talk in on 147.96/36, 224.5 and 146.52. For registration and information write Hamfest, DCARA, PO Bkox 236, Springfield, PA 19064 or call Barbara, N3DLG (215) 535-1616.

ONTARIO: April 11. The 6th annual Durham Region Flea Market sponsored by the South Pickering ARC. Pickering High School, Church Street N., Pickering Village, Ajax. Admission $3.00. Children under 12 free. Tables $6.00 each plus admission. For information, VE3DAX (416) 683-7562; VE3NBE (416) 839-9208; VE3JPP (416) 282-3983.

WEST VIRGINIA: April 5. Charleston WV Area Hamfest and Computer Show in Charleston Civic Center. 8 AM to 5 PM. Admission $4.00. Forums, SSTV, Packet, Flea Market and Swap Tables. Computer demos, ARRL booth. Talk in on 6.28/6.88. For information: Ollis Rinehart, KA8TIK, 1258 Ridge Drive, South Carleston, wV 25303. (304) 768-9534.

WISCONSIN: May 2. The Ozaukee Radio Club will sponsor its 8th annual Cedarburg Swapfest, Circle B Recreation Center, Highway 60 and County I, Cedarburg. 8 Am to 1 PM. Admission $2.00 advance, $3.00 at the door. 4' tables $3.00 each. Food and refreshments available. For tickets, reservations or information SASE to 1987 ORC Swapfest, 101 E. Clay Street, Saukville, WI 53080 or phone (414) 284-3271.

TEXAS: April 18. The Austin ARC's Spring Swapfest, Mancha-ca Fire Station on FM 1626. Open 7 AM. Free admission and parking. Tables $2.00. Talk in on 146.18/.78. For info: Dave Harper, WD5N, 109 W. 38, Austin, TX 78705. Tel (512) 454-9205 evenings.

NEW JERSEY May 17. The Bergen County ARA is sponsoring its Spring Hamfest, Bergen Community College, 400 Paramus Road, Paramus. 8 to 4 PM. Rain or shine. Buyers free. Sellers $5 per space, tailgate only. License exams. Talk in on 146.19/79 and .520 simplex. For further information: Jim, KK2U (201) 445-2855, 444 Berkshire Rd, Ridgewood, NJ 07450.

WISCONSIN: April 5. The Madison Area Repeater Association, (M.A.R.A.) is please to announce its 15th annual Madison Swapfest, Dane County Exposition Center Forum Building, Madison. Doors open 7:30 AM for flea market sellers and 8 AM for the general public. An all-you-can-eat pancake bareakfast available at the Swapfest. Admission $2.50 advance and $3.00 at the door. Children twelve and under admitted free. Flea market tables $5.00 each/advance and $6.00/door plus admission. The deadline for tickets and table reservations is March 31, 1987. For tickets, tables or information write M.A.R.A., PO Box 3403, Madison, WI 53704 or call (608) 274-5153 day or night.

OPERATING EVENTS

"Things to do . . ."

April 25. The Great River ARC of Dubuque, Iowa will operate N9GBY from 1600Z to 2300Z at the site of the annual Boy Scouts of America Grant Pilgrimage in Galena, Illinois. For a QSL card SASE to N9GBY, PO Box 141, Galena, IL 61036.

April 11. The St. Charles ARC will operate WB0HSI from 1400Z to 2200Z to celebrate its 15th anniversary near its original meeting site in St. Charles, MO. For certificates SASE to St. Charles ARC, PO Box 1429, St. Charles, MO 63302.

April 10, 11, 12. The Lanierland ARC will oeprate W4IKR 1400Z to 2200Z each day. To honor the 50th anniversary of the compietion of the Applachian trail, the 2000 mile hiking trail from Springer Mt. in Georgia to Mt. Katahdin in Maine. For commemorative certificate send QSL and 9x12 SASE (39 cents) to Lanierland ARC, PO Box 2182, Gainesville, GA 30503.

THE FOUNDATION FOR AMATEUR RADIO, INC. plans to award 26 scholarships for academic year 1987-88 to assist licensed Radio Amateurs who plan to pursue a full-time course of studies beyond high school and are enrolled or have been accepted by an accredited university, college or technical school. For further information write FAR Scholarships, 6903 Rhode Island Avenue, College Park, MD 20740 prior to May 31, 1987.

ARMED FORCES DAY 1987 May 16. The 38th annual Armed Forces Day Communication Test. Traditional military-to-Amateur cross band operation and broadcast of the Secretary of Defense message are the featured highlights and include operations in CW, SSB and RTTY.

MAY 1987 / $2.50

ham radio magazine

annual ANTENNA issue

ham radio
magazine

MAY 1987

volume 20, number 5

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail).
one year, $31.00; two years, $55.00; three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service): one year, $37.00
All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 111

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class *postage paid*
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents

REFLECTIONS

it used to be . . .

It used to be one of the major considerations in planning any antenna installation. After the wish list ("How many?" "What kind?" "How high?" "What bands?") was complete, reality entered the picture, raising such questions as "Can I really afford all this?" and "What kind of reception will I get?" This latter question often had less to do with performance and more to do with worrying about what the neighbors — and the zoning board — would say.

Radio Amateurs nationwide breathed (or should have breathed) a collective sigh of relief on February 12, 1987, when the courageous and persistent John Thernes, WM4T — who had taken on, at considerable personal expense, the city of Lakeside Park, Kentucky — won his case. In April, 1982, John had filed an application with the city zoning administrator for permission to erect a tower which was to include a triband beam at 70 feet and a two-element, 40-meter beam at 78 feet. (The specifics are important.) He was told, in effect, that the city's zoning regulations excluded *all* antenna towers. His application was rejected.

The details can be found in all the major Amateur Radio news reports (HR's *Presstop*, *The W5YI Report*, *The Westlink Report*, and *The ARRL Letter*) and in the other ham magazines, but basically what happened is that John took his struggle right on up to the Federal Appeals Court. And on February 12, the city of Lakeside Park agreed to sign a full consent judgment. What this meant to him was that he could now install his tower, his antennas, and his guy lines. There was a compromise — instead of a total height of 78 feet, he had to "settle" for 73 feet overall. (I believe I read that 73 feet would have been acceptable to John at the very beginning, before the city turned him down for any height at all.)

The significance of this case isn't that one Radio Amateur won his own personal antenna battle, but that *we all did*. . . because this was the first time that Memorandum Opinion and Order FCC 85-506, better known as PRB-1, was tested and supported in the higher courts. In its initial resolution, the Commission had declared that "local regulations which involve placement, screening or height of antennas based on health, safety or aesthetic considerations must reasonably accomodate amateur communications and represent the minimum practicable regulation to accomplish the purpose of the local authorities." In other words, it maintained that local and state governments cannot arbitrarily rule against the installation of Amateur Radio antennas.

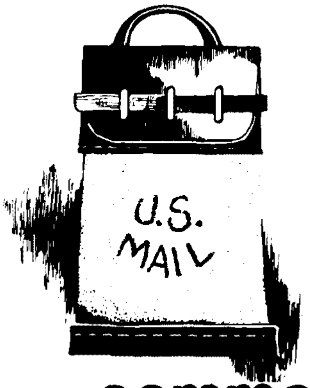
John's legal fees, I believe, exceeded $20,000. In deciding in his favor, the court ordered the city of Lakeside Park to pay all John's legal fees — almost $14,000 — incurred since the enactment of PRB-1. It now appears likely that any municipality that contests other proposed Amateur installations could very well lose and be held responsible for costs.

This is our annual antenna issue. Personally, I couldn't have asked for a more appropriate time to acknowledge and discuss WM4T's victory.

You can get a copy of the consent decree from the Northern Kentucky Tower Fund (P.O. Box 17721, Lakeside Park, Kentucky 41017; SASE appreciated). John, by the way, is reportedly still out approximately $7,000 of his own money; when you write for your copy of the decree, you may want to consider enclosing a donation to help minimize the impact.

Rich Rosen, K2RR
Editor-in-Chief

Amateurs interested in further developments in this and other cases may want to attend the Amateur Radio And The Law Forum conducted by attorney Jim O'Connell, W9WU, at 1 PM on Sunday, April 26, at this year's Dayton Hamvention.



comments

modifying the IC-02

Dear HR:

Readers may beinterested to know that the extended receive modification for the IC-02 described in my article, "Extending Receive Coverage for the IC-02 and IC-04" (July, 1986, page 77), will work for *all* IC-02 HTs, including those with serial numbers above 34,000.

Robert K. Morrow, Jr., WB6GTM
Flora, Indiana

Yagi design program

Dear HR:

Early in 1984, Jerry Haigwood, KY4Z, and I wrote a computer program, based on DL6WU's article in the March, 1982 issue of *VHF Communications*, for designing long Yagi antennas. We presented that program at the West Coast VHF Conference held in May of that year at Paso Robles, California. Therefore, it should be no surprise that I have looked very carefully at the program developed by VK4ZF and described in his article "Computer-Aided Design of Long VHF Yagi Antennas," which appeared in the May, 1986 issue of Ham Radio [page 28].

VK4ZF did an admirable job, but I believe that certain deficiencies should be pointed out. (The same could probably be done about the program Jerry and I wrote.)

First, the initial input requirement for the number of elements in the antenna is irrelevant. The initial criterion should be the desired gain or the available boom length. (Coincidentally, the irrelevance of the number of elements is covered by Joe Reisert in his column in the same issue [page 103]). Furthermore, in an earlier paper, DL6WU stated that the minimum boom length for an antenna of this type is about two wavelengths; a 2.2-wavelength boom will accommodate eight directors. There is no restriction as to the minimum number of elements in the program.

Second, the diameter of the elements is limited to the discrete values for which data files have been made. This makes it impossible to compare the program results directly with the example antennas described by DL6WU, although the differences are slight.

Third, the program is limited to 40 elements, which makes it impossible to compare the data for directors 39 through 47 of the 1296-MHz antenna described by DL6WU. There does not seem to be any valid reason for this limitation, since DL6WU states that his curves can be extrapolated almost indefinitely.

Fourth, the program limits the boom diameter to 0.05 wavelength, although this can be changed easily by modifying line 490. Without this change, it is impossible to use a boom diameter of 12.7 mm at 1296 MHz, which is the boom size used by DL6WU. Correspondence between DL6WU and KY4Z indicates that a minimum boom diameter of 0.075 wavelength is acceptable.

I have enclosed comparisons of the element lengths and spacings, showing DL6WU's figures, those obtained from VK4ZF's program, and those generated by the program written by KY4Z and me. A major discrepancy seems to be the length of the driven element in VK4ZF's program; it is far too short at 432 MHz, but slightly long at 1296 MHz.

None of the limitations described above exist in the program written by KY4Z and me, although the program does not include calculation of beam widths or stacking distances. Furthermore, it is a great deal easier to keyboard because the 16 data files are not required (which also conserves disk space).

Our program was written in Microsoft BASIC and will run under GWBASIC and BASICA. Minor editing may be required to convert it to other species of BASIC.

The program exists, under the filename DL6WU-1.BAS, on most of the RCPM bulletin boards in the San Francisco Bay Area, including KY4Z's AMPRO1 at 408-258-8128. I can also supply it in the following forms:

1. A listing, with a sample printout of results, for $1.00 (U.S.) plus a No. 10 (business-size) SASE. (Outside of the United States and Canada, send 10 IRCs.)

2. A 5.25-inch soft-sectored floppy disk for virtually any CPM computer (except Apple) or for any PC/MS-DOS computer. Be certain to specify the disk format desired (and an alternate, if possible) or the version of PC/MS-DOS that is used. The cost in the USA and Canada is $5.00 (U.S.), elsewhere, $7.00 (U.S.); this covers the cost of the disk, mailer, and postage. The same costs apply to either a disk or tape cassette for the Commodore 64.

Please address all requests to me.

Robert S. Stein, W6NBI
1849 Middleton Avenue
Los Altos, California 94022

any ideas?

Dear HR:

A friend installed a plastic owl on his beam to discourage birds. A real owl appeared and attempted to court the plastic owl. When the plastic owl failed to respond, it was attacked by the real owl, causing commotion and damage.

Any ideas, anyone?

Berand Kirschner
Oceanside, California 92056

two-element hf beams

Tune these medium-sized high performance antennas right from the shack

Physically small beam antennas that represent the least compromise in gain and directivity have been discussed in the literature.[1] Large antennas, for those for whom size is no problem, have received widespread coverage; the W2PV series of articles, for example, includes a wealth of material on large Yagis.[2] Yet the topic of medium-sized antennas — which includes the majority of Amateur beams — remains an area of uncertainty, about which many have sought without success for more information. The quad-versus-Yagi controversy continues unabated; conflicting claims are made for what might appear to be a bewildering variety of different beams, and an imperfect grasp of essentials has turned an inherently simple situation into one of needless complexity, with two-element beams deprived of their rightful status.

how small two-element beams work

In **fig. 1**, we have a bird's-eye view of two identical vertical elements carrying equal currents and spaced by a small fraction of a wavelength, with the plus and minus signs indicating that they are initially fed in opposite phase, thus tending to cancel each other.

At this point it's not important to know how the currents got there. Energy arriving at a specific point in space travels a different distance from each vertical element. This difference in path length and the opposite polarity of each vertical causes the maximum radiation from the array (two elements) to be along a line that goes through the elements. The two fields combine vectorially as shown in **fig. 1B**. For small angles, (ϕ_0) halving the angle halves the field. As one moves around the antenna, the difference is reduced; therefore the angle reduces, producing the directional pattern shown in **fig. 1C**, which is independent of spacing *as long as the angle remains small.* It follows that because energy remains similarly distributed throughout space, signal strengths must also be independent of spacing — provided there are no losses. Usually one introduces an electrical phase shift, ϕ. If this is equal to the spatial phase shift, ϕ_0, cancellation takes place in the reverse direction, producing the well-known cardioid pattern of **fig. 1D**. As the electrical phase shift, ϕ, is reduced, the null in the back direction splits into two. It gradually shifts around, with the back lobe increasing in strength until we arrive back at **fig. 1C**. However, for a given ratio of ϕ/ϕ_0, the pattern remains independent of spacing.

In the case of horizontal beams the directional pattern of the individual elements is superimposed on the beam patterns derived in accordance with **fig. 1**, but the principles are the same. Because no dimensions are mentioned, it follows that for two elements *the directive pattern — and therefore the gain — depend only upon the phase shift ratio, ϕ/ϕ_0, and are independent of the size, shape, or spacing of elements, provided the dimensions are not excessive*. This rule is reasonably accurate for element lengths up to about 0.7λ, and as shown in **fig. 2**, for spacings up to 0.2λ. It starts to break down if there are regions of high current that are separated by a substantial fraction of a wavelength, the $\lambda/4$ separation between top and bottom of a quad loop not being appreciable in this context. In this case, a directive pattern results through the addition of fields — a completely different mechanism that is the basic principle of large arrays. **Figure 2** shows the effect that element spacing has on gain and, from another source, a very similar curve for three elements.[3]

The basic statement emphasizing gain as primarily a function of the phase shift ratio rather than spacing — though it seems physically obvious — is in flat contradiction of widely published figures. These figures, derived mathematically for parasitic arrays, show gain and directivity to be *critically* dependent upon spacing and whether an element is tuned as a director or reflector. But although the calculations are indeed correct, they happen to be the wrong ones! More accurately stated, perhaps it's the designs to which they relate that are faulty, since I have assumed equal currents, whereas normally performance is sacrificed if the elements are straight.[5] As can be inferred from **fig. 3**, this is the worst possible shape because it minimizes coupling, consequently precluding the possibility of the presence of equal currents, except with very close

Les Moxon, G6XN, Gorse Hill, Tilford Road, Hindhead GU26 6SJ Surrey, England

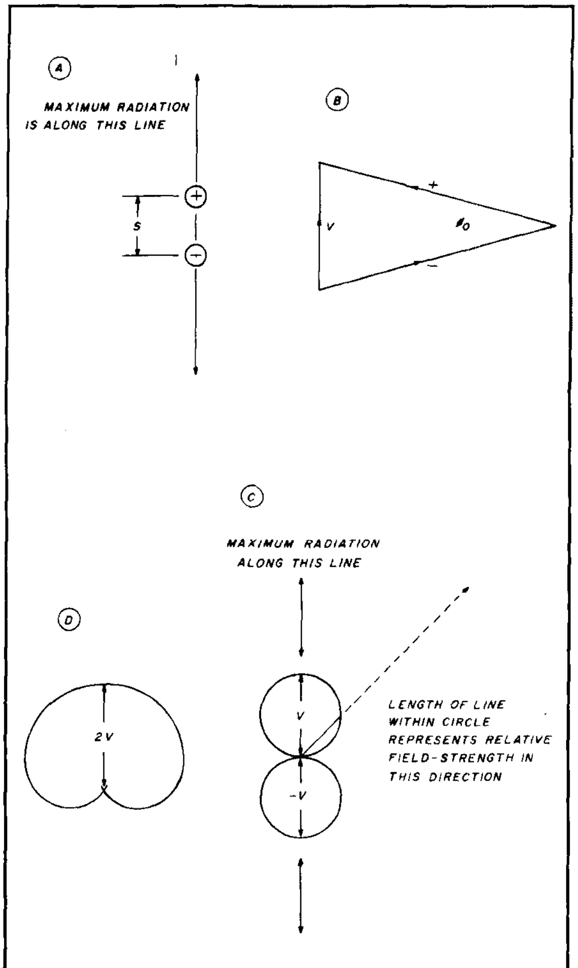


fig. 1. (A) Two closely-spaced sources separated by distance "S." (B) Vector addition results in voltage V that for small angles is proportional to ϕ_o. (C) Polar plot shows variation of field voltage as a function angle to observer. No additional (electrical) phase shift has been introduced — i.e., ϕ = 0. (D) Field pattern if electrical phase shift, ϕ equals physical phase shift (ϕ_o).

spacing (0.05λ). Nulls in the directional pattern are filled in and gain is also adversely affected.

Coupling between straight elements can be increased by moving them closer together. But for this to be effective, spacing has to be reduced to about 0.05λ, which is normally regarded as unacceptable because of reduction in bandwidth and efficiency. For this spacing, my calculations and those of W2PV are in close agreement. In my case, however, due to the assumption of equal current amplitudes, dependence on physical dimensions has been eliminated.

Inductive coupling (**fig. 3A**) isn't advised because of the reduction in radiation resistance. More often, natural coupling tends to be capacitive and needs only to be supplemented. One advantage of the quad is that loops couple more tightly than straight dipoles; this probably accounts for its popularity despite a poor reputation for survival in high winds. On the other hand, bent elements (see **figs. 3B** and **3C**) lend themselves to the design of more compact but equally efficient antennas with overcoupling rather than undercoupling as the more common fault. This is easy to correct either by an alteration of spacing or, if necessary, neutralization[1], as shown in **fig. 3C.**

mutual impedance

From the narrowing of the radiation pattern, it is evident that there must be gain relative to a dipole. But how, one might ask, can this be if the elements are tending to cancel each other? The answer lies in the fact that the element currents rise to whatever value may be necessary to account for the observed gain, and they can do so only by virtue of the *mutual resistance* between the elements which subtracts from the self-resistances when closely spaced elements are excited in antiphase. Without mutual resistance, there can be no power gain; these quantities are inseparable, so that given equal currents, one follows from the other. On the other hand, mutual resistance alone cannot achieve the degree of current equality necessary for obtaining deep nulls. This requires *mutual reactance*, which exists in most cases but may need to be increased or decreased, with reflector operation requiring negative reactance. Mutual resistance, R_m and reactance, X_m data appears to be available only for straight λ/2 elements (**fig. 4**), but the "size rule" implies that mutual resistance bears a constant relationship to the single-element radiation resistance (R), and so the mutual resistance can, if necessary, be inferred from it. Likewise, if the elements are self-resonant, mutual reactance can in principle be determined from

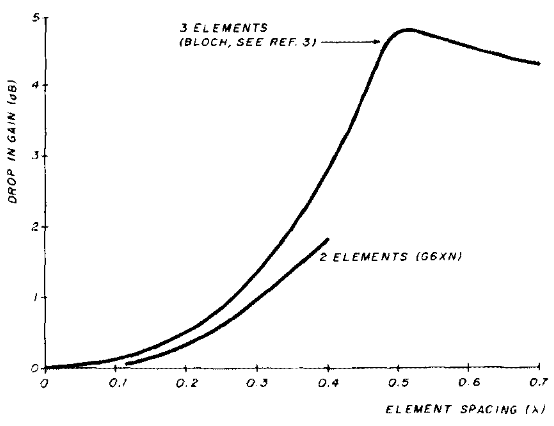


fig. 2. Decrease of gain with increase of spacing. Note that gain is a minimum for both two- and three-element beams as spacing diminishes though practical constraint impose a lower limit of about 0.1λ.

directions of minimum response by obtaining corresponding values of ϕ/ϕ_0 from **fig. 5**, since with no detuning the phase shift ϕ is determined solely by the phase angle of the mutual impedance — i.e. by X_m/R_m so that by knowing ϕ, ϕ_0 and R_m we can evaluate X_m. This method has not been evaluated in practice and its use is restricted by the fact that with large departures of X_m from its optimum value the nulls will not be deep enough for their direction to be determined. In general, however, with two elements there should be no need to know the actual value of X_m since constructions are available which allow it to be adjusted by trial and error. Additionally, by virtue of the "size rule" calculations or measurements for a set of dimensions for which X_m is known can be applied to any other, with due allowances for differences in R. Calculations, simplified by assuming equal currents,[5] have led to further results:

- Radiation resistance (R_B) for a parasitic array is given by

$$R_B = 2\,(R - R_M \cos\phi)$$

- For an array in which each element has its own feedline, the radiation resistances are:

$$R\ director = R - R_M \cos\phi + X_M \sin\phi$$

$$R\ reflector = R - R_M \cos\phi - X_M \sin\phi$$

With a resonant reflector and equal currents, the null directions are approximately 130 degrees relative to the beam heading in all cases. The total resistance is the same as before, but that of the reflector (or director if X_M is positive) can be zero or even negative, which bodes ill for the matching process. Until now, driven operation has been the usual method of trying to equalize currents, but the reason for some failures may now be apparent, particularly because the usual phasing lines must be matched for correct operation. Solutions to this problem have been discussed before.[1,5] Driven operation remains a possible solution to the problem of obtaining equal *currents* with straight elements, and a number of such antennas have been described. Most of these, intended to be reversible, specify λ/4 spacing, which is too wide, or λ/8 spacing, which is convenient and simplifies the mathematics to the extent that X_M disappears. Unfortunately, because of mutual reactances of opposite sign, which each element induces into the other, a very high VSWR exists in each of the individual feeders. This high VSWR may not be noticed because it doesn't appear in the common feed from the transmitter; if it were corrected, the beam couldn't be reversed because the correction would then be of the wrong sign and make matters worse. Open wire lines can be used, but result in excessively narrow bandwidth (though I've overcome this by using folded dipole elements).

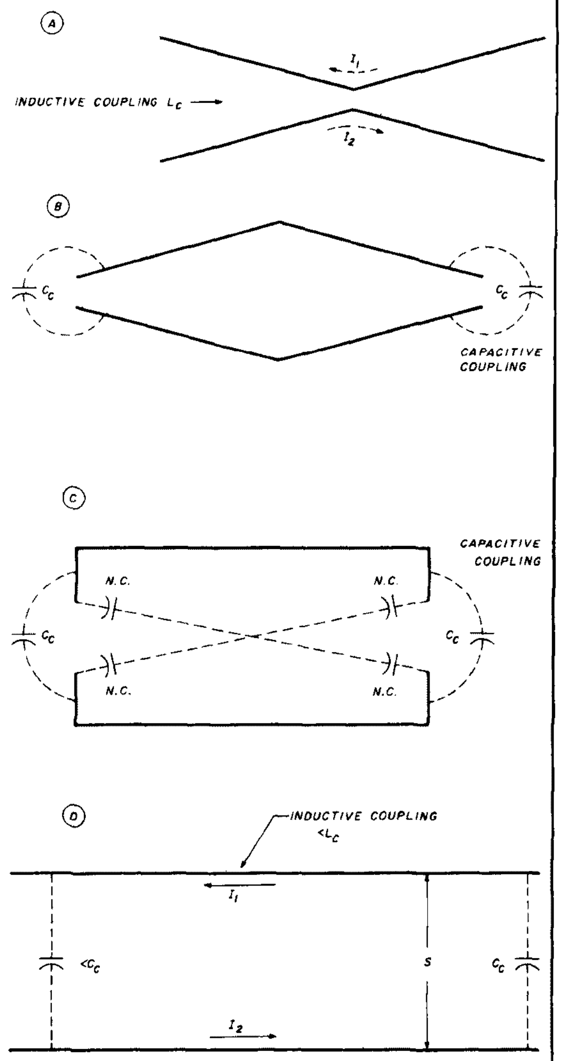


fig. 3. Inductive and capacitive coupling of two elements. (A) Elements bent inwards at their centers couple inductively. (B, C) Ends bent inwards couple capacitively. (D) Excessive coupling may be neutralized by capacitors as shown in (C). In (D), the two couplings cancel each other if S = λ/8, leaving only the resistive coupling, R. Straight elements minimize coupling.

Overcoupling is a problem likely to be experienced in the case of quads with less than 0.15λ spacing. The "Swiss Quad" (with 0.1λ spacing) gets around this by driven operation, but as we'll discuss later, there are many advantages to be derived from resonant feeders, including the possibility of increasing coupling or neutralizing excess coupling by means of capacitance between the lines. **Figure 5** shows the dependence of gain, radiation resistance, and null directions on the phase shift ratio.[1,5] If any one of these quantities is known, all the others except radiation resistance (R_B)

follow from it. For the last parameter, we also need to know the value for a single element (R); with a few exceptions, this can be obtained from **fig. 6**. The method of calculation is explained in reference 5. **Figure 7** is a further extension of **fig. 5** showing the direction and magnitude of the back lobes in the radiation pattern. They demonstrate the crucial importance of the ratio ϕ/ϕ_0 in determining *all* aspects of the performance of two-element beams (including bandwidth, since this is linked to radiation resistance, as discussed later).

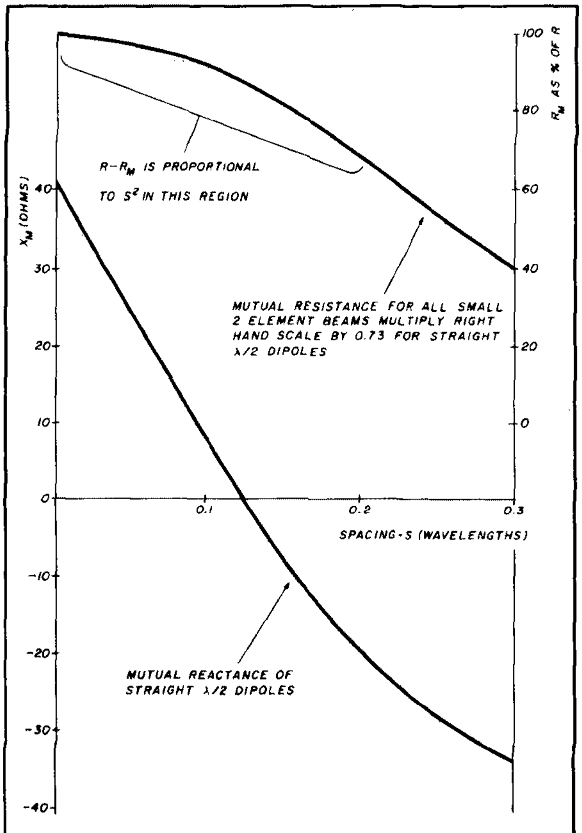


fig. 4. Mutual resistance R_m and mutual reactance X_m as a function of spacing for two-element beams.

directivity gain

So far we've assumed that there are no losses. Apart from feeder loss, other losses may occur because of proximity to nearby structures, use of very thin wire, or as the limiting factor when trying to make an antenna as small as possible. Besides radiation pattern distortion, currents induced in booms or supporting structures due to lack of symmetry may introduce additional losses. If equal currents and correct phasing are maintained, losses as such have no effect on directivity which, because of high external noise levels, is usually the sole requirement in the case of reception on the hf bands.

Losses can make it impossible to equalize currents by means of increased coupling, but there is then no longer any problem with driven operation since the mutual resistance, as a result of these losses, is no longer in control of the situation. Because of this, it's customary to distinguish between directivity gain and power gain, the two being equal when there are no losses.

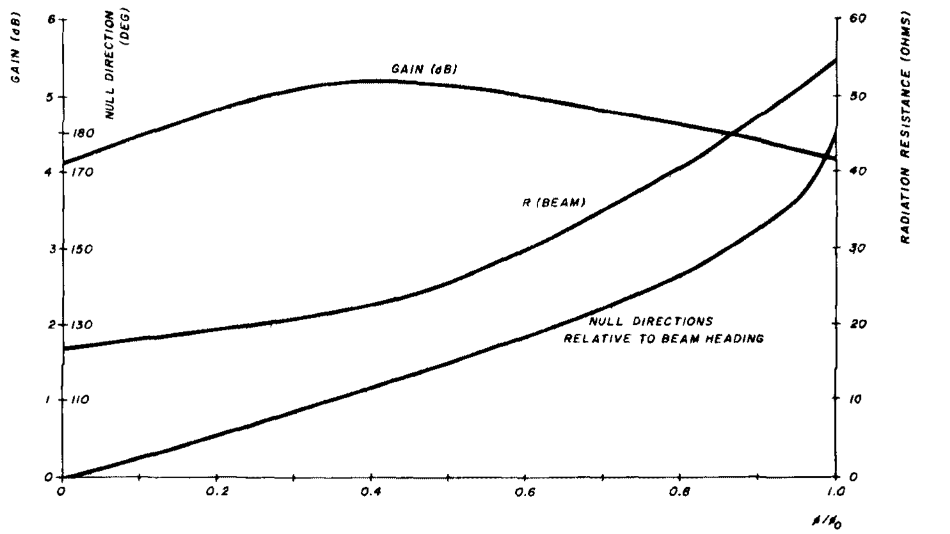


fig. 5. Relationship between phase angle, gain, null directions, and radiation resistance for all close-spaced, two-element beams with equal current drive. Note: losses not included; gain figures valid within 0.3 dB for null depths > 10 dB (approx.). Radiation resistance (in ohms) for half-wave elements spaced λ/8 (see text for other beams).

losses

Horizontal monoband hf beam losses rarely exceed a few ohms, and with radiation resistances of a few tens of ohms, can usually be neglected. In doubtful cases they can be roughly estimated from conductor sizes, assuming one has some idea of the current distribution.

Resistance data in graph form can be found in textbooks, but a handy figure to remember is one ohm per half-wavelength for 3-mm diameter copper wire (approximately No.10 AWG) at 14 MHz. The loss is inversely proportional to diameter and to the square root of frequency. However, divide by 2 for long conductors that have a sine wave current distribution, such as antenna wires or resonant feeders. This gives the resistance referred to a point of maximum current, which is standard practice also in the case of the radiation resistance with which it must be compared. For parallel wires, divide by the number of wires; for aluminum alloy, multiply by 1.6, and don't use iron or steel!

bandwidth

Bandwidth is roughly proportional to radiation resistance but also varies inversely with the length of the resonant system (which includes the antenna up to the point of matching). We are interested in two kinds of bandwidth:

• **SWR bandwidth** — i.e., the frequency range over which the SWR is less than 2.0. As might be expected by analogy with coupled circuits, bandwidth in this sense is improved by tighter coupling between elements. The better the SWR bandwidth, the less frequently the antenna tuner has to be readjusted, or the better the chance of being able to dispense with it. In general, SWR tends to rise steeply at the low frequency end of the tuning range, since tuning low is equivalent to tuning the reflector higher. This reduces ϕ, causing a shift to the left on the curves shown in **fig. 5**, with R_B dropping to a relatively low value.

• **Pattern bandwidth**, or the frequency range in which a specified null depth such as 10 dB is exceeded or the forward gain remains within 1 dB of maximum. Despite their relatively small size the antennas to be described here come close to meeting the above specifications on *most bands without retuning the* reflector. This is consistent with a reasonable degree of operating convenience, but to take advantage of very deep nulls it's essential for the reflector to be connected through its own feeder to a tuning device at the operating position. In this case, pattern bandwidth is less important but makes for added convenience. Use of two feeders provides an additional bonus: the ability to reverse beam direction.

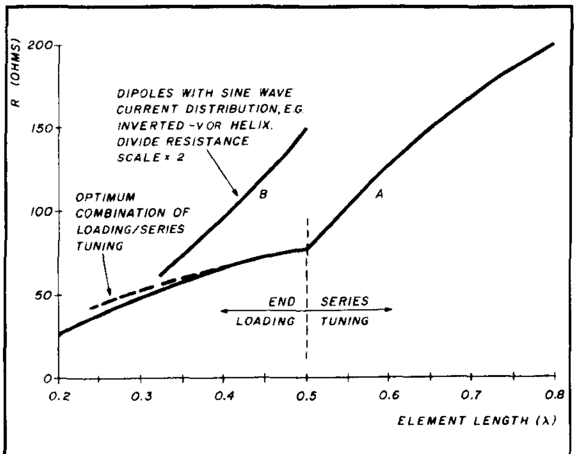


fig. 6. Radiation resistance of (A) "best possible" dipoie elements (includes fig. 8C) and (B) resonant λ/2 dipoles fitting into restricted space (e.g., fig. 8D) — in this case, R is proportional to (1/length)².

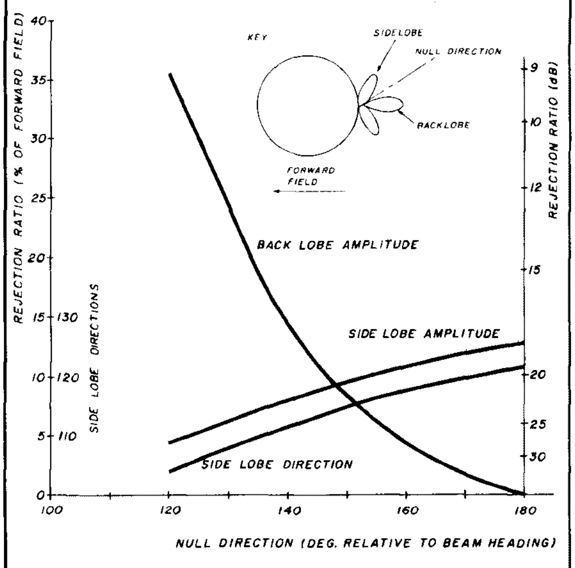
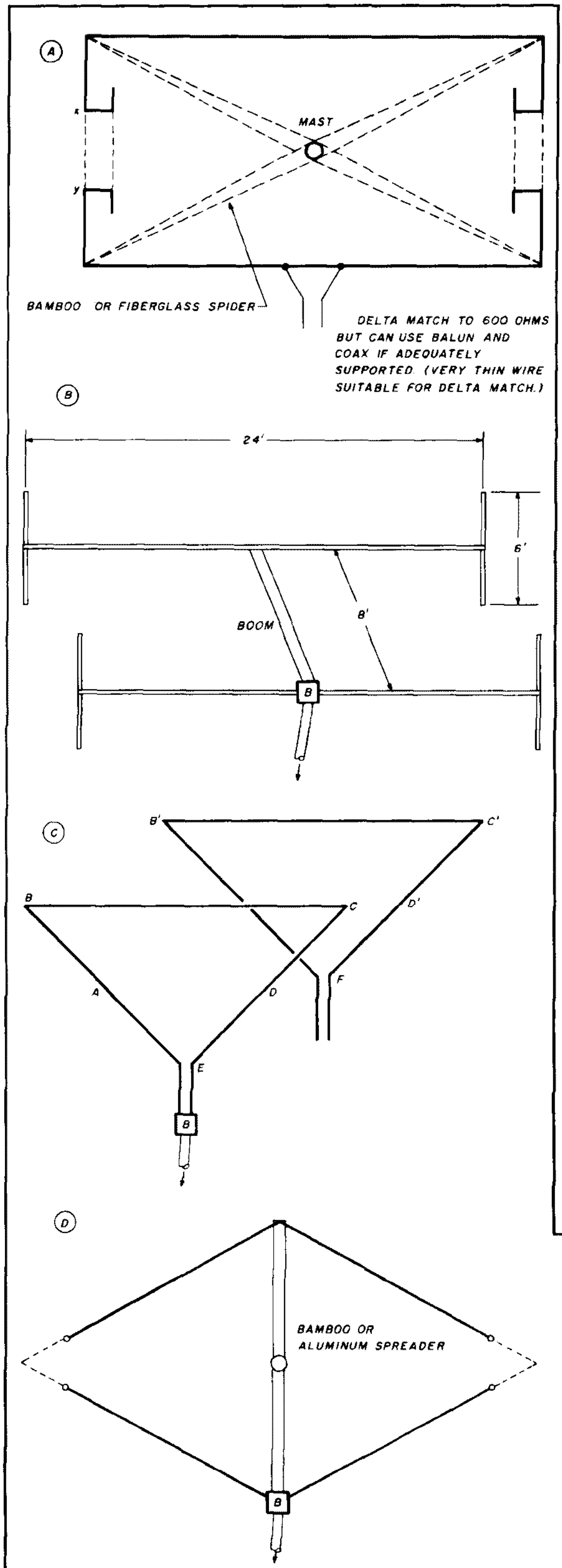


fig. 7. Size and direction of back lobes (see key, abovel. For corresponding gains, see *fig. 5*.

design of elements

Although elements don't have to be identical, it usually helps — and is essential if one wants to be able to reverse beam direction without having to retune. **Figure 6** shows that half-wave elements can be reduced by 30 percent in length for only a trivial reduction (17 percent) in radiation resistance, provided capacitive end-loading (or its equivalent) is used. **Figure 8** shows three practical ways of achieving this. In the case of **fig. 8C**, *AB* and *CD* act solely as end



loading because radiation from them is cancelled by that from *AE* and *DE*.

Most of the designs to be described are based on the small delta loop (**fig. 8C**), which can be suspended between the tips of fiberglass fishing rods angled upwards, thus achieving an effective height considerably in excess of the mast height, since there's little or no radiation from the sides of the loop. In this form it has become known as "The Claw" for reasons obvious from the photograph (**fig. 15**). In most cases there seems to be little point in exceeding an element span of about 35 percent of the longest wavelength to be used; further size reduction is governed by three main constraints: bandwidth, losses, and difficulty of folding enough loading wire into the space available. For a reasonable approximation to "full size" performance, the above length can be more than halved if some form of remote tuning is provided.[1] Practical difficulties escalate rapidly as the span length drops below 0.25λ.

The arrangement shown in **fig. 8D** can be erected as an inverted V and is important as an alternative option though the sinusoidal current distribution halves the radiation resistance for a given span.

coupling and null depth

All four arrangements shown in **fig. 8** provide increased coupling. In cases A and D, this is readily adjustable by altering the spacing between ends; 30 inches for a span of 20 to 24 feet at 14 MHz has been found suitable, but some experiments may be advisable. Ajustment of coupling isn't critical. I've found that "design by guesswork" frequently produces null depths in excess of 20 dB. It's best for errors to be corrected in the antenna itself, but for fine tuning, placing capacitors between convenient points on feeders has been found satisfactory. These can be connected either in phase to increase coupling or out of phase to neutralize excessive coupling. I then find it possible to get null depths usually in excess of 20 dB, and often much greater, for all back directions and in-band (14 MHz) frequencies with single-knob tuning of

fig. 8. Two-element horizontal beams with reduced length and enhanced coupling. Reflector should preferably be a duplicate of the driven element (see text). Otherwise, if currents equal (i.e. if deep nulls are obtainable), tune reflector to the low edge of desired band. (A) Bent dipole elements (20 x 10 feet suggested, though dimensions are not critical) xy (nylon fishing line) $\approx$ 30 inches. (B) End-loading by vertical rods. Single elements have been used successfully with the dimensions shown. Coupling may need augmenting. (C) Small delta loops (ABCD) should be just over $\lambda/2$. Size can be reduced by small loading stubs. BB′ may be 0.12-0.2λ; EF < BB′/2. (D) Erect between posts or as inverted V. Spreader (or boom) may be 9-12 feet for 14 MHz.

the reflector. "Deepest possible" nulls aren't thought to be worth additional effort, given the unstable nature of the ionosphere and sensitivity to local field disturbances — for example, trees blowing in the wind, the presence of other antennas, even aircraft reflections. Up to 30 dB can be useful, but deeper nulls require precise adjustments of phase and amplitude (two knobs). By the time these adjustments are made, the interference one is trying to remove has probably disappeared anyway! With deep nulls a tendency has been observed for non-reciprocity between transmission and reception, due probably to pickup on wiring in the shack. If a linear is used, this won't be identical for the two cases.

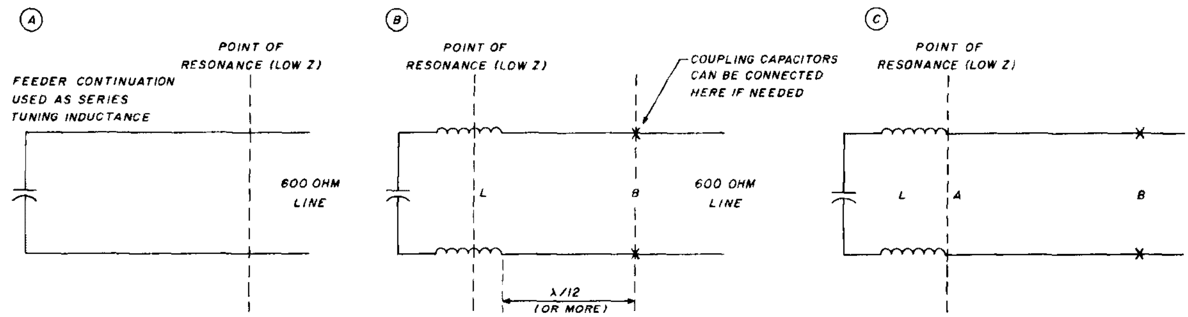


fig. 9. Reflector tuning of "Claw" antenna: (A) Long feedline; (B) short feedline; (C) resonant feedline. This method, especially as illustrated in (B), is convenient, since point B is more likely to be accessible. Total L = 3.5 μH. Terminations can be band-switched, but often cover two or three bands.

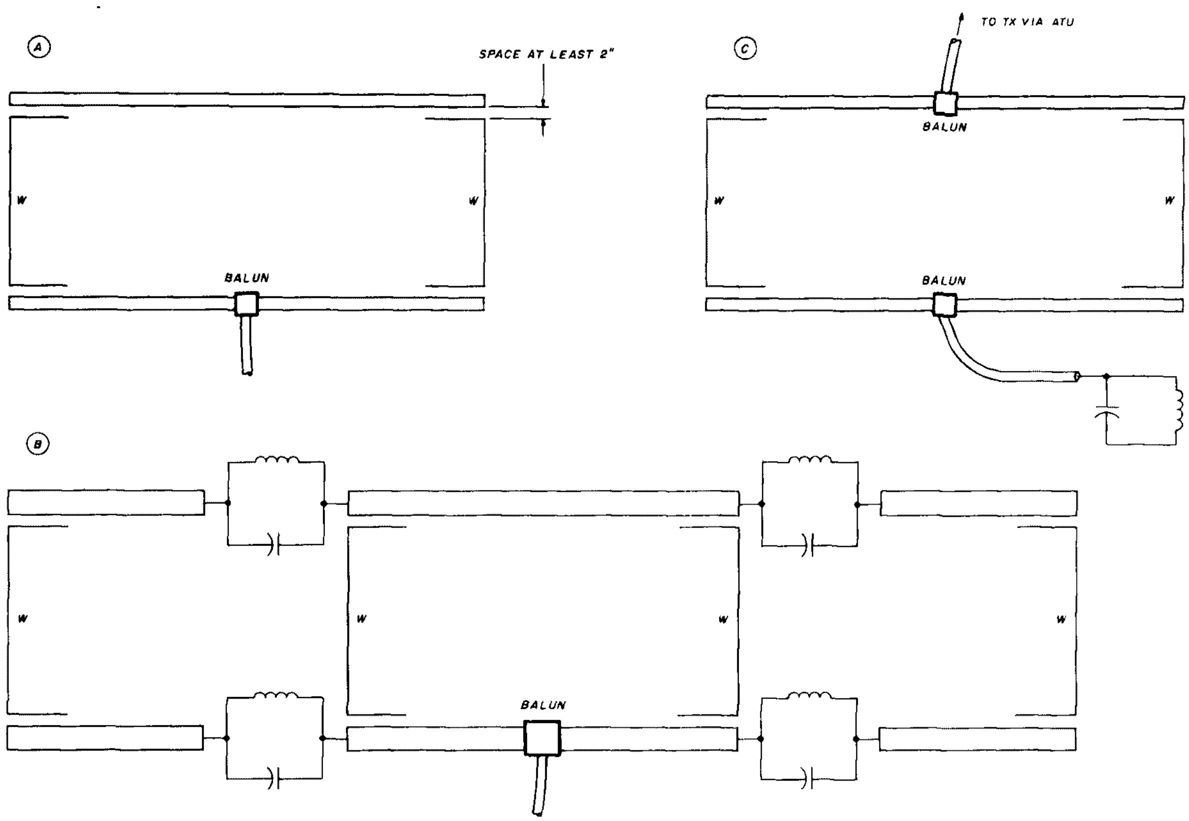


fig. 10. Application of enhanced coupling to conventional beams. (A) monobander — coupling wires (w) suggested as alternatives to bending the elements. (B) Beam with traps. (C) is similar to A, except in that the reflector is tuned via the feeder.

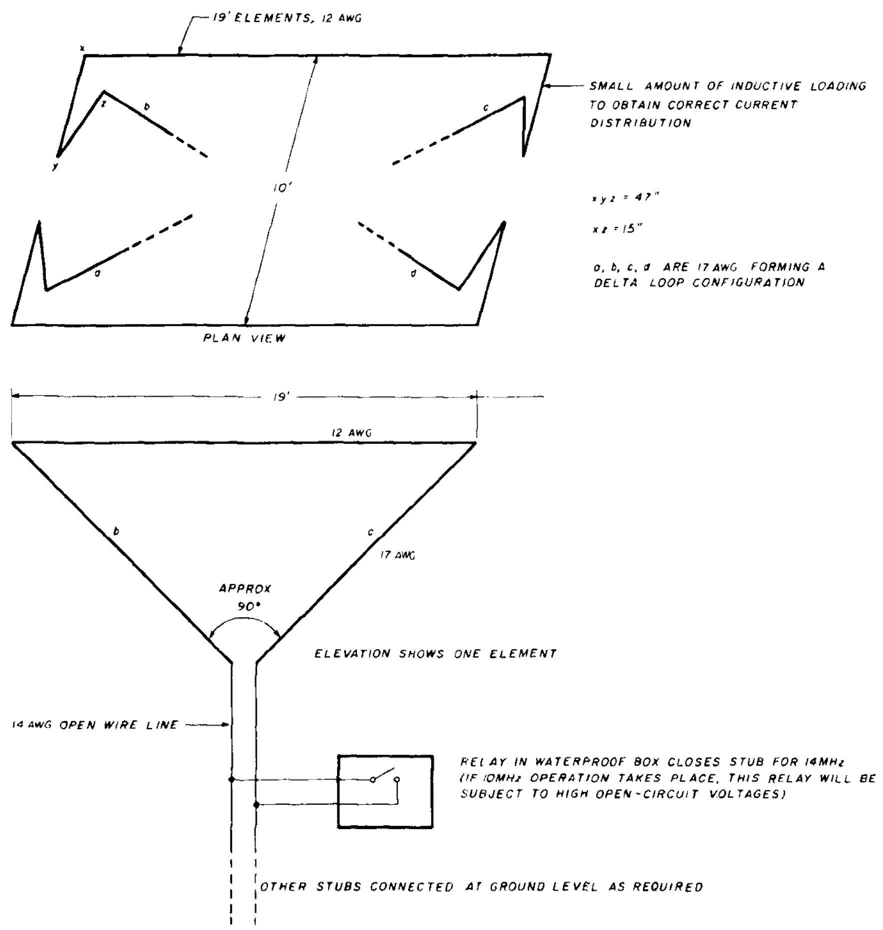


fig. 11. Wire beam based on the small delta loop. In plan view, this may be recognized also as a derivative of the VK2ABQ antenna. Wires should not be attached directly to bamboo supporting arms. Lengths of nylon fishing line should be used as insulators. (Reproduced with permission from RSGB.)

reflections from other antennas

These reflections can be large enough to seriously degrade forward gain at distances of over 30 meters at 14 MHz. (In one case I observed a loss of 2 S-units due to screening by another antenna at about 25 meters.) Their effect on front/back ratio is much greater. From mutual resistance data, it appears that another antenna 7 wavelengths away might be expected to degrade a 30-dB null by about 6 dB. Such effects depend, of course, on the extent to which the interfering antenna is in the beam path, so the effective radiation pattern varies with beam heading. The interfering antenna may be "removed" by detuning or rotating it to an end-on position, but any front/back ratio *it* may possess applies *only to its own* input terminals and does nothing to help. Unless such effects can be eliminated, the possibility for serious errors remains. This further emphasizes the importance of being able to make adjustments at the operating position to suit the needs of the moment. However good its f/b ratio, a large Yagi will still be wide open to reflected signals from other antennas in its beam path.

reflector tuners and t/r switching

Separate optimization of transmitting and receiving characteristics by switching between two different reflector tuners is a further important option. Tuning of the reflector to null out an interfering station can have a large effect on the SWR unless the antenna tuner is readjusted. Using an FS710H automatic in-line SWR meter, I haven't found this to be a problem, but without such a device and with modern solid-state amplifiers it can be an embarrassment. Because transmitting and receiving requirements aren't identical, it makes sense, in any case, to use separate tuners switched by a relay, not forgetting to use the "trans-

mit" (tuner) condition when checking for prior channel occupancy. While any feeder length can be used, it simplifies matters to choose one that allows series tuning as shown in **fig. 9**, preferably as shown in **fig. 9B**, which increases the chance that points such as *xx*, where the rf voltage is suitable for coupling adjustment, will still be available in the shack if required. With feeder impedances of both 50 and 600 ohms at 14 MHz, I have found a capacitance (C) of 40 to 250 pF and an inductance (L) of 3 to 4 μH to be suitable, but this would depend on feeder length. The trick is to pick a likely-looking capacitor out of the junk box and, with a grid dip oscillator, find an inductance that allows the reflector to be tuned through the band and down to about 2 percent lower.

beam reversal

This reduces the average time required for changing beam heading since rotation can be limited to about 140 degrees. Also, in many cases an Armstrong method of rotation can be employed, with two ropes substituted for the usual heavy, expensive, and sometimes unreliable beam rotator. It can be particularly useful in multi-way contacts, and if there's uncertainty about whether propagation is short or long path. It also provides confirmation that the antenna is working correctly. **Figure 10** includes suggestions for the addition of controlled coupling to conventional beams which, though as yet untried, may be useful to experimenters. In (A) and (C), it may be easier to pull the ends in toward each other with nylon fishing line. To permit beam reversal and null-steering, the reflector must be replaced by a replica of the driven element.

comparison between two and three elements

Two-element beams can be expected to produce deeper and more controllable nulls, but this may not help if more than one interference source is present. In this respect, three-element beams are superior, assuming fixed tuning of the reflector in both cases. With two elements, a rejection ratio better than 18 dB can be obtained for all back angles if the nulls are placed at 150 degrees to the beam heading; this is for a spot frequency, but can be obtained throughout the band if reflector tuning is synchronized with the main tuning. With three elements, W2PV[2] found null depths in excess of 20 dB over 2 percent bandwidth in the best case, but this was only for the 180 degree direction. It has also been shown that three elements can provide rejection in excess of 28 dB at all back angles simultaneously on a spot frequency.[4] From tuning data given in this reference, I estimate a minimum rejection of around 18 to 20 dB over a 2 percent band, which is little better than the two-element result and requires very precise adjustment of the kind difficult to obtain in practice because one is working with too many variables. The two-element beam, moreover, provides the option of deeper nulls in specific directions, though the rejection of QRM from several sources simultaneously may then be adversely affected. In practice, not more than 1 to 1-1/2 dB extra gain can be expected from the third element, and in terms of the low-angle radiation required for chordal-hop propagation (which is probably responsible for most long-haul DX[5]), this is equivalent to an antenna height increase of only 15 to 20 percent. The small size, light weight, and construction of antennas described in the next section should, in many cases, lead to height increases of this order. It is not suggested that these small beams can compete with a six-element monobander on a 100-foot tower, but they can hold their own in more ordinary circumstances, requiring only a modest means of support, indifferent results quoted by earlier authors being attributable entirely to the assumption of straight elements and the resulting current inequalities. Much of this ground has been covered in earlier publications; a complete bibliography can be found in reference 5.

multiband beams

Multiband beams have previously consisted mainly of tribanders involving some degree of compromise. Instead of using the whole of a 14-MHz $\lambda/2$ element on 28 MHz, it is cut down to size by traps, or 28-MHz loops are stacked inside 14-MHz loops which could be used to provide extra gain on 28 MHz. This sacrifices 2 to 4 dB of gain at 28 MHz[1], as well as incurring losses due to circulating currents in traps or "wrong way" currents induced in unused elements, which can reduce bandwidth and affect coupling.

Trapped beams rate highly in terms of convenience as well as off-the-shelf availability, and their popularity could no doubt be further enhanced by design improvements — for example, along lines suggested by W0JF.[11] At the same time, the fact that now we have, within 1-1/2 octaves, six bands instead of three, presents an exciting challenge unlikely to be met by traps or stacking without further compromises. The log periodic antenna, though simple in use, is large, heavy, expensive, and inferior in performance to a Yagi of the same size.

the "poor man's log periodic" (PMLP)

When short of new ideas, it often helps to take a fresh look at old ones, which is what I've been doing in the case of resonant feeders. Though these have been *blamed* for TVI, radiation from balanced lines is very small, and they've consequently also been *recommended* as cures for TVI. It's true that they can get themselves twisted around the mast or entangled in guy ropes, but there's no excuse for this if beams are

reversible as previously recommended, since rotation can then be restricted to less than 180 degrees. A more serious objection is the restriction of bandwidth. But with remote tuning, this becomes an inconvenience rather than a basic limitation. Now, through a fortunate accident, a solution to the bandwidth problem has also emerged and with it a family of small, lightweight antennas that provide the performance and other characteristics of the antennas described earlier, yet are tunable over the frequency range from 10 to 30 MHz. This largely achieves the object of the log periodic antenna, though the principle at work is entirely different.

the ideal antenna?

To establish the respectability of resonant feeders and provide a useful perspective, the design of a "best possible" multiband beam will be attempted.

Consider three identical straight tubing elements 44 feet *long, spaced 8 feet apart,* fed with about 46 feet of open wire line, and tuned to 14 MHz. The radiation resistance of a single element is 150 ohms and the bandwidth of antenna *plus* feeder for an SWR *of* 2:1 is about 8 percent, differing only slightly from that of a normal half-wave element. This should provide gain and f/b ratio in line with the previous three-element example. The larger value of radiation resistance, however, makes it much easier to use resonant feeders for remote tuning and beam reversal; even if this is not required, it helps to ensure reasonable bandwidth. The main benefit occurs at other frequencies, since on 28 MHz the elements are "extended double Zepp," which was the reason for the choice of length. The boom length is nearly optimum,[2] bringing the total gain to about 10.5 dBd. The spacing is too wide for good f/b ratio on 28 MHz, but this could be improved by additional coupling. On 10 MHz, omitting the center element provides for satisfactory spacing and achievable gain is in accordance with numbers indicated in **fig. 5**. Losses are negligible. The lower end of the feeders is assumed to be accessible near the antenna and can be lengthened or matched into, if necessary, utilizing band switching, depending either on local requirements or bandwidth considerations. With two elements, the boom length would have to be reduced, with 0.1λ the minimum acceptable length at 10 MHz. The gain at 28 MHz is reduced to 7 dB, but remains high for two elements. For comparison, the gain of a log periodic will be in the region of 6 dBd, assuming a boom length of 50 feet, making the PMLP far superior except for the inconvenience of having to tune it. This can be done in the shack if the feeders aren't too long. Nevertheless even the PMLP in this ideal form is in the "monster" class, and much effort has been devoted to applying the same principles to smaller antennas.

the small delta loop

The antenna shown in **fig. 8C**, a fixed pair of loops supported by a tree, was selected for this purpose after being used initially as the quickest and easiest way of getting back on the air from a new location. Though it wasn't possible to make a direct comparison, the performance of a full-size quad — in the same tree at the same height — was later judged to be about the same. The first multiband version of this antenna[6], shown in **fig. 11**, was used initially without the switched stubs, with correct coupling established by capacitance between the corner stubs (which also provided a small amount of loading) and by bringing the lower corners in towards the mast. The electrical lengths from top center to a shorting bar at ground level were arranged to be λ on 14 MHz, 1-1/2λ on 21 MHz, and 2λ on 28 MHz, providing for 600-ohm feedline matching as well. Current nulls in the center of the sides on 14 MHz ensured that all the radiation was from the top of the system, while at higher frequencies the loops radiated as ordinary loops, with effec*tive spacing r*educed by bringing the lower corners together. The matched lines (120 feet) were taken respectively to an antenna tuner and a series-tuned circuit for *reflector* tuning via a *beam-reversing switch* which interchanged the feeders in the shack. The elements were supported by four 8-foot bamboo garden canes radiating outwards and upwards from an aluminum hub with four 4-foot spokes, for a total radial length of 12 feet. The SWR bandwidth for given settings of the antenna tuner and reflector tuning at 14 MHz was only 100 kHz which generated a tendency to stay in one part of the band. Differences in tuning between wet and dry weather were a nuisance. These were aggravated by short lengths of 300-ohm line initially used for bypassing the rotating joint. Checking the feasibility of operation on 10 MHz was difficult because it required the attachment of matching stubs at half the mast height, but it was achieved on one occasion, which resulted in an S8 report from VK with reasonable f/b ratio.

Despite the narrow bandwidth, such an arrangement may well be acceptable on the grounds that it is simple, cheap, versatile, and efficient, especially if the shack is located at the base of the mast. For me, however, it has one fatal flaw: the difficulty of living with the knowledge that identical performance could be obtained from a smaller antenna! To improve bandwidth on 14 MHz, the stubs were moved a half wavelength closer to the loops, with relays to disconnect them as shown in **figs. 11** and **12**. This enabled tuning for the 21- and 28-MHz band, where the radiation resistance is much higher, to be carried out at ground level as before.

The small delta loop is mechanically superior to a

center-fed bent dipole (**fig. 8A**), since the center of the element doesn't have to support the weight of the feeder. Other features include higher radiation resistance and reduced effective spacing on 21 and 28 MHz, but on 14 MHz an adverse impedance transformation takes place at the bottom corner of the loops so that an estimated radiation resistance of 45 ohms referred to the top center is stepped down to only 20 ohms in the feeder. Using the relay as shown, this isn't important, since only a short length of line is affected. But with no relay and No. 14 AWG feeders, there's an estimated loss of 1 dB, as well as the narrow bandwidth already noted. With tubing elements as shown in **fig. 12**, the situation is more favorable, with an estimated impedance reduction of only 30 percent. There's also more flexibility because the impedance discontinuity at the ends of the tubing tends to offset the step-down at the bottom corner and the boom can, if necessary, be used to support a heavier feeder system.

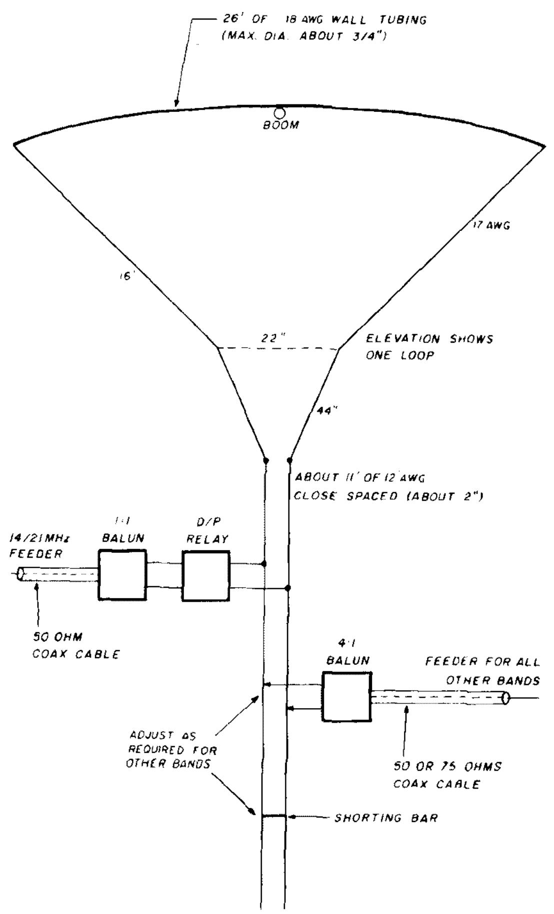


fig. 12. One element of small delta loop array using tubing end-fed with wires. These wires can be thin because current zeros occur at the crosspoints on 14 MHz, and on higher frequency bands Rg is relatively large. Element spacing is with the lower corners 4 feet apart. (Reproduced with permission of RSGB.)

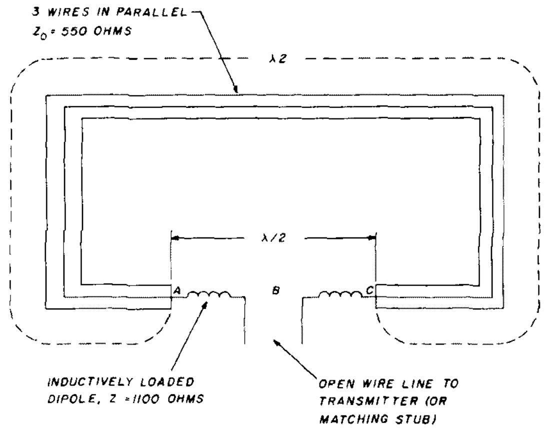


fig. 13A. Example of the impedance transforming loop showing principle of operation. (A) Loop acts as pair of λ/4 transformers so that a radiation resistance R appears (in this case) as 4R at the feedpoint.

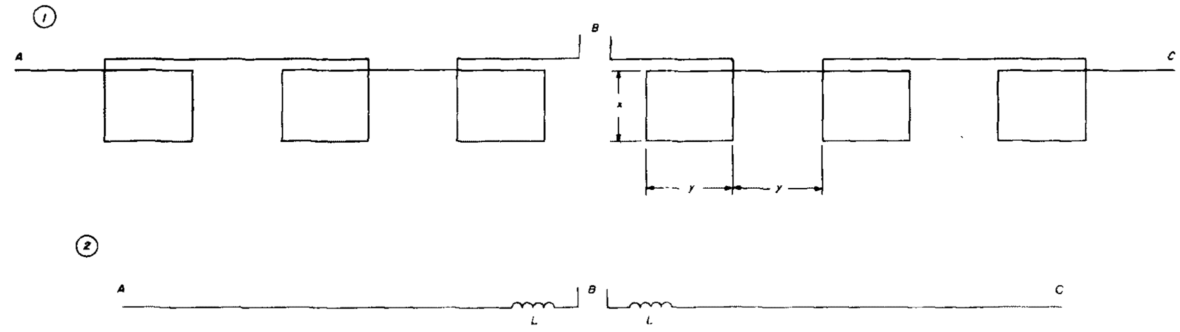
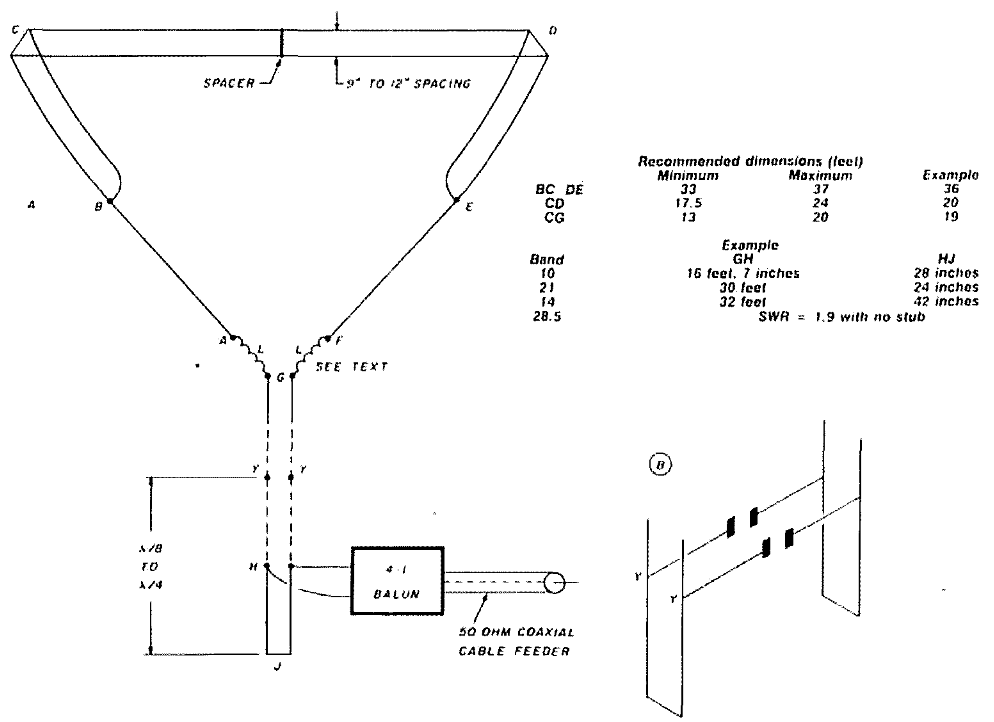


fig. 13B. Alternative forms of inductively loaded dipole. Note: in (1), x = 10 inches, y = 15 inches (at 14 MHz). In (2), AB = BC = 9 feet; each L is a 40-turn, 1-inch diameter, 20-inch coil.



	Recommended dimensions (feet) Minimum	Maximum	Example
BC DE	33	37	36
CD	17.5	24	20
CG	13	20	19

Band	Example GH	HJ
10	16 feet, 7 inches	28 inches
21	30 feet	24 inches
14	32 feet	42 inches
28.5	SWR = 1.9 with no stub	

fig. 14. Claw antenna design: (A) exact shape isn't critical (see fig. 15); (B) small capacitors are used to adjust coupling if necessary. (Reproduced with permission of RSGB.)

Figures 11 and **12** represent two extremes of design in which "anything goes." Typical observed SWR and f/b ratios are included in **table 1**. No additional coupling or neutralization was needed to obtain the results shown. In the case of the **fig. 12** configuration, it must be assumed that although on 14 MHz the radiation was coming from straight elements, the "quad loop effect" was operative with respect to coupling. In the antenna shown in **fig. 12**, it was found that for two-band operation (14 and 21 MHz), the relay could be omitted because of a chance combination of impedance transformations which caused the second harmonic resonance to occur at only 1-1/2 times the signal frequency. In general, I've not found it difficult to obtain efficient two-band operation of antennas without switching, but three bands are much more difficult.

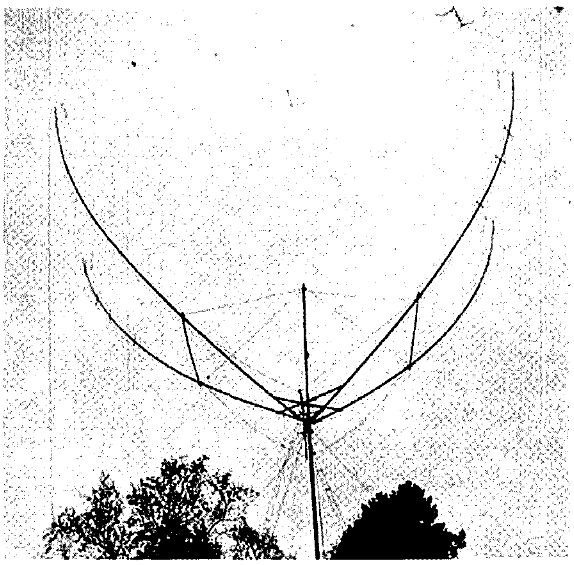


fig. 15. The Claw antenna.

the impedance transforming loop(ITL)

Disadvantages of the systems illustrated in **figs. 11** and **12** include the need for switches or relays in positions that are usually inaccessible. Even if this is acceptable, frequency coverage is restricted because as R decreases, switching devices have to meet increasingly stringent requirements with respect to capacitance and rf voltages.

Figures 13, 14, and **15** show a means of dispensing with relays and, to a large extent, the need for matching stubs. This was the outcome of an unsuccessful attempt to develop a small (i.e., 18-foot, 14 MHz) broadband folded dipole by slowing down the wave velocity.[8] The idea was to trick the wave into thinking

Table 1. Comparison of various antennas described in this article.

BAND (MHz)	Antenna	Bandwidth for F/B ratio >20dB	>15dB	>10dB	Bandwidth for SWR <1.25	<1.5	<2.0
14	S.D.L. (wire)		140	280	110	190	300
	S.D.L. (tube)	150	220	385	225	390	
	Claw No. 1	40	120	220	160		330
	Claw No. 2		145	300			230
	Folded Dipole			230	100	260	350
21	S.D.L. (wire)			320	110	205	370
	S.D.L. (tube)			550	360		
	Claw No. 1	85	210	350	330	420	
	Claw No. 2			400		320	380
	Folded Dipole			260			450
28	S.D.L. (wire)				190		500
	S.D.L. (tube)			800	550	800	
	Claw No. 1		240-300	600	180	370	680
	Claw No. 2	170	840	1000		1000	
	Folded Dipole					280	1000

the element was larger, but this was unsuccessful. Being difficult to draw and of limited practical interest, its somewhat fearsome appearance will not be inflicted on the reader, though some performance figures are included in **table 1**. The surprise came in the form of a chance discovery that long feeders could be connected without degrading the bandwidth; the explanation, though elusive, led eventually to the design of a number of antennas bearing little resemblance to the original dipoles.[7,9]

principles of operation

Figure 13A illustrates a small loop element which could be any shape. Two or more half-wave wires are used in parallel for the top part of the loop, resulting in a low value of characteristic impedance Z_{OT}.

The remainder of the loop consists of a second $\lambda/2$ dipole with a high value of characteristic impedance, Z_{OB}; this can be a helix as shown, or inductively loaded in other ways. Each dipole functions as a $\lambda/4$ transformer so that the radiation resistance, R, after being stepped up to the value

$$Z_{OT}^2 / R$$

at the ends of the top dipole, is then stepped down to

$$(Z_{OB} / Z_{OT})^2 \cdot R$$

at the feedpoint. As illustrated, a typical R value of 50 ohms is stepped up to 200 ohms at the feedpoint, which is high enough to ensure that bandwidth remains an intrinsic property of the antenna and is free from serious degradation due to the feeder. A selection of Z values is given in **table 2**. Depending on size and construction, the lower dipole may be a thin wire unloaded V or one of the alternatives shown in **fig. 13B**. All of these arrangements have been used successfully. The usual objections to inductive loading don't apply because the radiation is mainly from the top part of the loop. This comes about because the current is stepped down in the ratio of the impedances; because the lower dipole is shorter; and because the current distribution in it is sinusoidal or triangular, in contrast to the almost uniform current in the top dipole. This constitutes a major advantage over the quad loop, in which the mean height is dragged down by radiation from the lower side. On the other hand, there is some radiation from the sides; it can be cancelled

Table 2. Design data for ITL antennas.

Characteristic impedance for various wire sizes and combinations.

Number of conductors	Diameter (inches)	Spacing (inches)	Z_0(ohms)
1	0.04		1000
1	0.8		650
2	0.04	4	690
2	0.04	6	640
2	0.04	12	550
3	0.04	4	550
4	0.04	4	490

Equivalent Z_0 of lower dipole (wire diameter, 0.04 inches) with inductive loading.

Physical length of dipole (wavelengths)	Equivalent Z_0 (ohms)
0.375	1200
0.3	1500
0.25	2000
0.2	29000

Note: Z_0 values are calculated for 14 MHz. However, because of some length dependance, they will be slightly different for other bands. No data is available for helical windings.

by reverting to a more or less triangular shape as shown in **fig. 14.** Assuming an ITL to be designed for 14 MHz, operation on the higher frequency bands differs little from that of the small delta loops described earlier; at 21 MHz there tends to be some "wrong-way" impedance transformation, suggesting the desirability of matching stubs at ground level in the case of long feeders. Concentrated loading, as shown

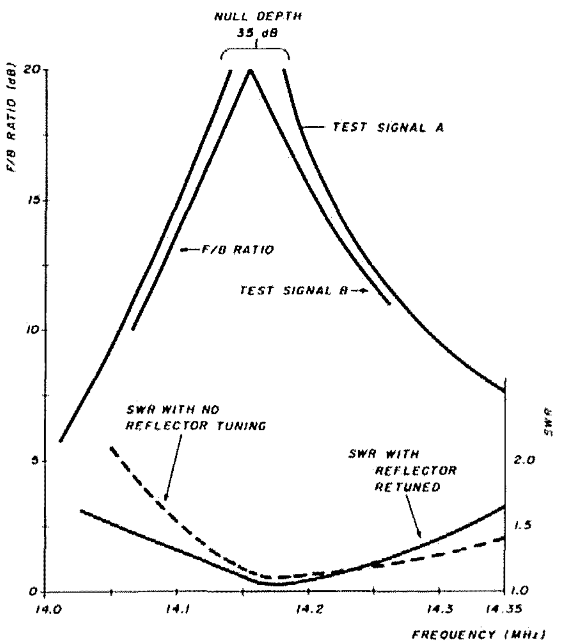


fig. 16. Typical performance of Claw No. 1 on 14 MHz. F/B ratio curves demonstrate null-filling due to any slight error in adjustment. In this case, one test signal was slightly too close. SWR rapidly increases as the π approaches zero. The reflector was adjusted for nulls at 140-150 degrees, but curves were roughly repeatable over a range of 110-180 inches without readjustment of coupling.

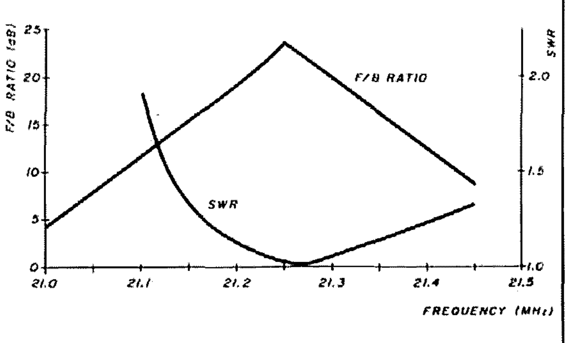


fig. 17. Typical performance of Claw No. 1 on 21 MHz. Note steep rise in SWR at low frequencies — i.e., as ϕ decreases.

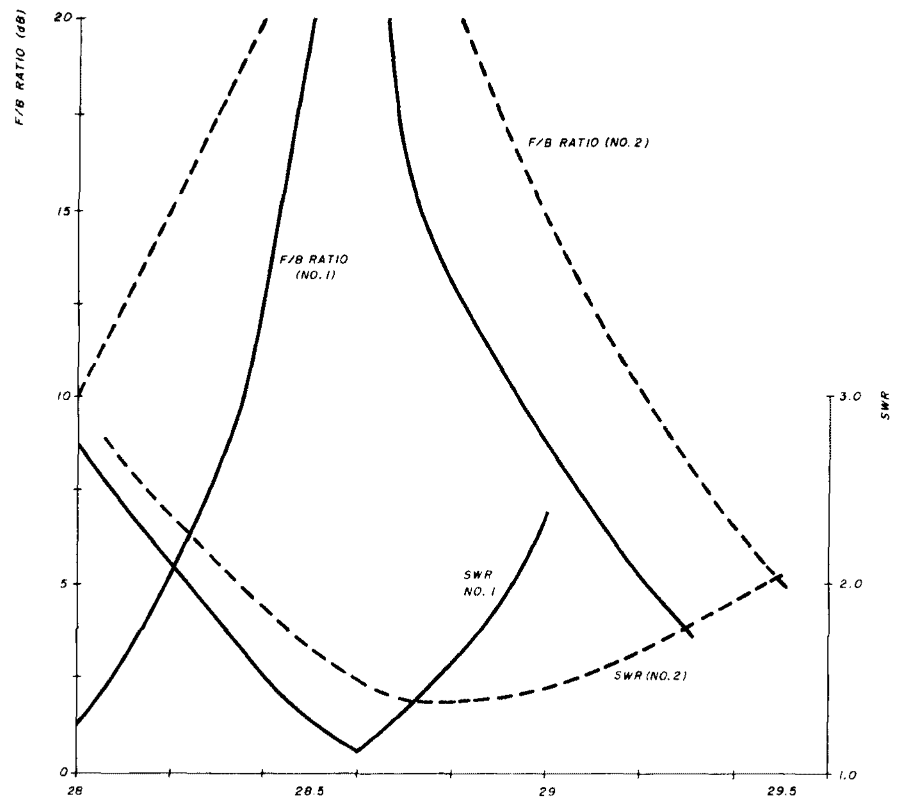


fig. 18. Typical performance of both Claws on 28 MHz. Curves demonstrate adverse effects on bandwidth of very long unmatched feeder.

in fig. 13B2, improves matters on 14 MHz by increasing Z_{OB} (see table 2), but reference to a Smith Chart suggests that at 21 MHz this could lead to an increase of SWR in the open-wire line of 2 or more. On the other hand, with long coils of small diameter (20 inches x 1 inch), as shown in fig. 14, much better agreement between theory and practice resulted from regarding them as a harmless continuation of the traveling wave system.

construction

Figures 14 and 15 illustrate the latest version of the Claw antenna, which uses two pairs of fiberglass fishing rods 13 feet long, extended at their lower ends by an additional 6 feet of 1-inch diameter fiberglass tubing. These are plugged into alloy sockets which radiate outwards from the top of the mast. They are braced back with further lengths of fiberglass tubing to a short mast extension. The elements are held apart by 6-foot spacing rods of 1/2-inch diameter alloy tubing. Plastic rod end-pieces are used to keep the rods a few inches clear of the elements; even so, these may be responsible for some of the coupling. The tips of the fishing rods are pulled in by nylon fishing line to give an element spacing of 12 feet. Points on the rods are guyed back to crosspieces at the top of the mast. The top wires are held 11 inches apart in the horizontal plane by fiberglass spacers cut from the discarded tips of the fishing rods. Additional spacers on the rods themselves (with fishing-line ties) are used to maintain even tension in the wires to avoid flexing and breakage. Earlier versions used three copper wires spaced 4 inches apart, but the benefit from the extra wire hardly justifies the added complication (see table 2). The latest version uses No. 16 AWG aluminum alloy wire, which reduces weight for a given rf resistance, but increases windage. Since the rf resistance is only half that of a single wire, mechanical considerations are more likely to be the deciding factor. Wires break if not kept under tension, but with two antennas over a period of three years — which has included periods of heavy winds — no fishing rods have broken, and there has been no other damage to the main structures.

The same wire gauge is used throughout. The loading helices are each wound with 40 turns over a total

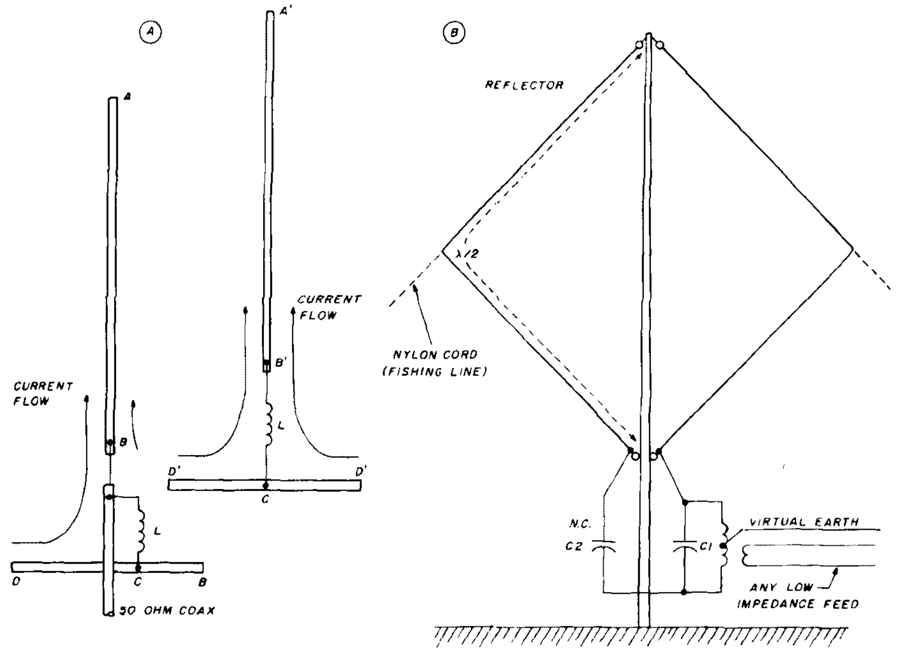


fig. 19. Vertical arrays. (A) Asymetrical dipolr array can be mounted on fence posts. To adjust coupling, swivel around to alter spacing DD'. (B) Maypole array.

length of 20 inches, partly near the lower end of the rod extensions and partly on the bracing struts. Because of the low radiation resistance on 10 MHz, it's advisable to provide matching as close as possible to the antenna. In one case, 28-inch stubs were placed 16 feet, 7 inches from the element. Later, for greater convenience I used a pair of series-connected 10-pF capacitors near ground level. The location could be determined by finding points of "zero" current and then moving 3 feet closer to the antenna. Matching on the other bands was used initially, but discarded because it made no difference in signal strengths, though **table 1** suggests the loss of some bandwidth. Even on 10 MHz, despite the additional 120 feet of open wire line (No. 19 AWG), the loss without matching was less than one S-unit. Measured performance data for both Claw antennas is included in **table 1**. The plots of f/b ratio and SWR shown in **figs. 16, 17** and **18** are typical of results obtained with Claw No. 1.

alternative designs

The loops can also be suspended from spreaders between two supports. In this case planar loading (an idea suggested to me by Steve Hart, VK5HA), as shown in **fig. 13B**, is suggested. The assembly can be supported by three lengths of nylon fishing line with small ring insulators cut from fiberglass tubing to keep adjacent edges apart. I find that nearly a 3:1 reduction in length can be achieved this way; because it uses less wire, its efficiency is greater than with helical loading. For this reason, it was used in the first two versions of the Claw,[7] but helical windings in this case are easier and neater, with losses insignificant. Similar loops can be suspended from their centers in inverted V fashion. I've also built a rotary version of such an antenna modelled after the one shown in **fig. 3B**. This used a lightweight mast extension surmounted by a 1/2-inch diameter aluminum boom. Two fiberglass radial arms were used to hold up the dipole ends. Apart from the neutralization problem mentioned earlier, this worked well on 14 MHz. A three-element version of the Claw was also constructed; since only triband operation was required, I was able to use a coaxial feeder for the center element and a relay to switch in an additional length of helix on 21 MHz. The third element was effective on 28 MHz and was indirectly useful for 10 MHz because, though not in use, it allowed wider spacing between the other two elements without degradation of performance on 28 MHz. On 14 and 21 MHz, there was no improvement compared to using any one of the three possible pairs on its own. SWR on 14 MHz could be varied between 1.0 and at least 5.0 by tuning the parasitic elements! The problem was basically one of "too many variables," and it was concluded that for three elements to be viable, they would need to be spread out along

a boom; the "Claw" concept would then lose most of its attraction in return for a relatively small improvement in performance.

vertical arrays

Vertical beams can also be constructed using controlled coupling.[10] **Figure 19** shows two examples. The first is an "asymmetrical dipole" array that uses inductively-loaded counterpoises to form the lower half of the dipoles. The inductances can take the form of linear loading.[5] The elements are movable and can be plugged into sockets on fence posts. Coupling is varied by rotating the counterpoises towards each other and all adjustments are conveniently accessible. Each half of the dipole should be resonated separately against a $\lambda/4$ wire. The second can be regarded as a "vertical VK2ABQ" antenna. It's best to use four wires at right angles; adjacent pairs may be connected in parallel, though they can also be used in a three-element configuration. In the two-element case, which is recommended, overcoupling was experienced, requiring neutralization as shown. ("Zepp feed" can also be used, provided the open end of the feeder is closed with a $\lambda/4$ stub[5,10] as recommended by G6CJ.)

conclusion

My intention has been to provide guidelines, rather than blueprints, for the construction of antennas tailored to suit individual needs. The Claw designs will be useful even if the best mast available is only a garden post, and I hope that some who have decided regretfully that beams are "not for them" will have second thoughts. The null-steering and beam-reversal capabilities are particularly useful. In addition to coverage of six bands — with "monoband" performance on several — Claw elements are particularly suitable for use as top-loaded verticals for the lower-frequency bands.

references

1. L. A. Moxon, G6XN, "Small Beams with Big Performance," *ham radio*, March, 1979, page 12.
2. J. L. Lawson, W2PV, "Yagi Antenna Design," *ham radio*, May 1980, page 18.
3. Bloch, Medhurst and Pool, "A New Approach to The Design of Super-directive Aerial Arrays," *Proceedings of the IEE*, Part III, September, 1953.
4. W. Walkinshaw, "Theoretical Treatment of Short Yagi Aerials," *Journal of the IEEE*, Part IIIA, March-May, 1948, page 598.
5. L. A. Moxon, G6XN, "HF Antennas for All Locations," *Radio Society of Great Britain*, 1982.
6. Pat Hawker, G3VA, "Technical Topics: Multiband Arrays with 'KISS,'" *Radio Communication*, August, 1983, page 705.
7. Pat Hawker, G3VA, "Technical Topics," *Radio Communication*, March, 1985.
8. Pat Hawker, G3VA, "Technical Topics: Antennas That Slow The Wave," *Radio Communication*, April 1984, page 316.
9. Pat Hawker, G3VA, "The 'Claw Mark 4' Antenna," *Radio Communication*, January 1987, page 28.
10. F. Charman, G6CJ, "Aerial Reflection," *R.S.G.B. Bulletin*, December, 1955.
11. Private communication.

G6XN's book, *HF Antennas for All Locations* is available from Ham Radio's Bookstore for $11.95 plus $3.50 S&H.

ham radio

homebrew antenna mount

Hand tools and standard hardware are all you need for this project

A number of years ago I visited a ham friend who proudly showed me his new tribander. Sitting atop a rotatable mast secured to a ground-mounted fixture, the antenna could also be lowered so that one could work on it comfortably.

We lived in an apartment then, and the only antennas I could install were dipoles for 80 and 40 meters and a vertical for 20, 15, and 10. Later, when we finally bought a home, I found that despite a large back yard, power and telephone lines — as well as trees we'd planted — put an end to my plans for an antenna farm.

Though finding antennas for 80 and 40 meters was no great chore, finding room for a tower or mast was. It was then I realized I already had a platform for working on my antenna — namely, the gently sloping garage roof. I decided I might be able to put up something similar to the arrangement my friend had shown me years before.

My plan was to use a push-up mast, supported somehow at the bottom, and drive it, with the antenna on top, from ground level. I did some shopping for parts and spent some time at the work bench; using hand tools only (with the exception of an electric drill), the result was a mast which has been in use now for a dozen years or more, with no problems (**Photo 1**).

initial considerations

One of the first things to realize is that your antenna isn't going to rotate at 5000 rpm. It turns *very* slowly (my rotor takes a full minute to turn 360 degrees), and hence puts little strain on the bearing you'll use. Aside from the inevitable accumulation of dirt, which is easily removed with a stiff brush and some paint thinner, I've had no problems with the bearing at all.

The second thing to realize is that when you have everything done, extending the push-up mast with the antenna on top of it isn't easy unless you've made some advance preparations. Suppose you've acquired such a mast; it will probably have three or four sections, depending on the height you've chosen. Mine has four, and the outside diameter of the lowest section is 2-1/4 inches. The lifting problem isn't one of weight, but of having some way of knowing when you're reaching the point at which you should stop lifting and secure the section with the clamp provided, and maybe even drill to pass a 1/4-inch bolt through the two sections if you're a bit timid.

mast inspection

Lay the mast out on the ground, *fully extended*, and examine the point at which the smallest section emerges from the one below it.

Although the smaller section of my mast won't separate from the larger one, there's an illusion at work: when you're lifting the smallest section, with the antenna mounted on it, you become absolutely convinced that at some point the whole thing will pull out, leaving you on the roof with 10 feet of mast and an antenna in your hands and nothing else to hold them. To avoid this, use paint or some other marker to warn you when you're just a few inches from the clamp-off point. Do this with all of the sections. At this point, let me add a caution: whenever you're extending or collapsing the mast, wear heavy gloves! (I use a pair of leather gardening gloves.) The mast sections have a nasty habit of pinching your flesh between them. *Wear those gloves!*

mounting the mast

Decide where you'll mount the mast. For aesthetic reasons, an exterior garage wall is a good choice; you may prefer to attach hardware through to the exposed studs rather than to a finished interior or exterior wall of your house.

You'll also have to decide how far off the ground the lower end of the mast will be supported. This will

Howard A. Bowman, W6QIR, 5872 West 77th Place, Los Angeles, California 90045

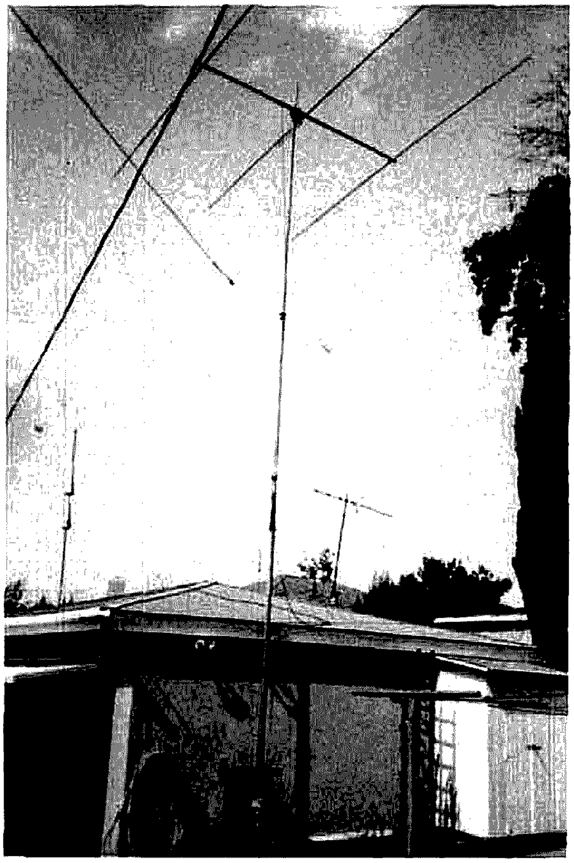


Photo 1. Complete installation.

depend on the length of your rotor, which will hang below the "shelf" you'll build (see **photo 2**), and should clear the earth by a few inches. At this point, do one other thing as well: measure the inside diameter of the lowest section of your mast.

Before you head out to the plumbing supply shop, try to visualize what your array of mast, rotor, and connecting pieces of pipe will look like overall. A short length of pipe should fit snugly inside the lower end of the mast. (Though it doesn't have to be an exact fit, it should be fairly close.) It should be 5 or 6 inches long and threaded on both ends; you'll find it at your local plumbing supply house, described as a "nipple." You'll also need two lengths of pipe — one to run from the support you'll build to the upper clamp of your rotor, and the other to run from the lower clamp of the rotor to about a foot below the surface of the earth. One end of the upper piece must be threaded. Aside from this, it's probably simpler to get one long piece and cut it in half yourself.

You'll also need a reducing fitting. At its larger end, it should accept the threads on the nipple, and at its smaller end it should accept the threads on the longer piece of pipe. Caution: pipe sizes are guaranteed to confuse everyone in the world except plumbers. Pay no attention to the designated pipe sizes; use a tape or a scale and measure everything for yourself. Try the mating pieces to be sure they do what they're supposed to do. That way you won't encounter unwelcome surprises.

The next step takes place in your own workshop. Screw the nipple tightly into the reducing fitting, securing it by drilling and tapping for a machine screw of some convenient size. (The screw won't bear any load, but will keep the two parts from coming apart.) Then slide the nipple into the lowest section of the mast until the lower edge of the mast section rests on the reducing fitting.

At this point I drilled and tapped for 1/4 inch x 20 machine screws and used hex-head screws about 1/2 inch long. This was overkill, but, to some extent, the number of screws you use will depend on the snugness of the fit between the lowest mast section and the pipe inside it. The idea is to square things up as well as you can. If you need four screws 90 degrees apart, use them.

You'll need a bearing with an inside diameter large enough to accept the smaller end of the reducing fitting. The tapered shoulder of the fitting will ride on the inner race of the bearing. I've used two bearings — one a standard ball bearing and the other a tapered roller bearing. Either does fine. The inside diameter of each is 1-5/8 inches, and the outside diameter is just a bit over 3 inches. It's important that the slanted portion of the reducing fitting fit inside the bearing, so take careful measurements or take the fitting with you when you shop for the bearing at an establishment that stocks new and used machinery. In a pinch, you may find one at an automobile junkyard.

mast and rotor support

Having come this far, you've done all but the drudgery of making some kind of a support for the mast and rotor. Mine is made of ordinary 1-1/4 inch angle iron, which you can find at any iron fabricating shop or even at some large hardware stores. If you get it at a hardware store, it will most likely be sold in 6-foot lengths; you'll need three of them. If you get it from a shop, be careful. Be sure of your measurements, since the cutter may distort the metal where the cuts are made, making part of it unusable for your purpose.

In planning your shelf, be sure to consider its height above ground and its depth. The shelf must be high enough so that your rotor can hang below it with a few inches clearance above ground. Its depth depends upon the distance your mast will be positioned from the wall. In my case, eaves extend 7 inches from the wall, meaning that my shelf had to be about 15 inches deep to allow the mast to clear the eaves and still

provide adequate support. If you have no eaves to contend with, you may be able to make the shelf only 8 or 10 inches deep. (Keep in mind that this dimension will have some effect on the amount of angle iron you'll need.)

triangular supports

The next step is to make two right-angled triangles out of angle iron. They should be made so that they're mirror images of each other; that is, each should have the open sides of the angle iron pieces facing the other. One leg of the triangle will extend outward from the wall, another will fit vertically against the wall, and the third will complete the triangle by extending from some point near the outer edge of the horizontal piece to some point toward the lower end of the vertical piece.

Start by drilling both the vertical and horizontal pieces where they overlap and bolt them together. I used 1/4-inch bolts on mine. Use a square to make certain that the angles form a 90-degree angle. Measure carefully for the third leg, cut it to size, and, once again, drill for bolts. Do the same with the other three pieces of angle iron, making sure that the open sides of the triangles face each other.

Now, try to mount these triangles — at least temporarily — to the wall to which they'll be bolted. Once you've decided how far your shelf is to be above ground, locate a point on a stud adjacent to where you want to mount the antenna. (That point should be 2 or 3 inches below the intended level of the shelf.) Drill a small hole through from the inside, keeping it as close to the center of the stud as you can. Now move to the stud on the other side of the intended location and drill a similar hole. These holes should go all the way through the studs and the outside covering of the wall.

Locate one of the triangles over the small hole, have someone hold it there, go back inside with your drill, and, using the hole through the stud as a pilot, drill into the metal of the triangle at least far enough to make a mark. Now both holes can be enlarged to accept a 5/16-inch diameter bolt. You can also drill another hole in the triangle vertical leg toward its lower end. Align things carefully so that the leg is vertical, then drill through the wall and the stud for a second bolt.

Studs are sometimes not exactly vertical, so this hole may be a bit off center. Don't worry. If the triangle is vertical and your bolt has a good bite on the wood of the stud, you'll be all right. Use a washer under the head of the bolt, and a fender washer (one that is larger in diameter), a lock washer, and a nut on the inside.

Locating the second triangle is a bit tricky because you want its top and the top of the first triangle to be as level as possible. The easiest way to do this is to have someone hold the second triangle against the wall so that one edge of the vertical leg is beside the hole you've drilled through the wall, and so that a spirit level across from the first triangle to the second shows that both are at the same height. Carefully mark the angle iron beside the point at which you've drilled, then drill the angle iron for the bolt. Locate the position of the second bolt just as you did for the other triangle.

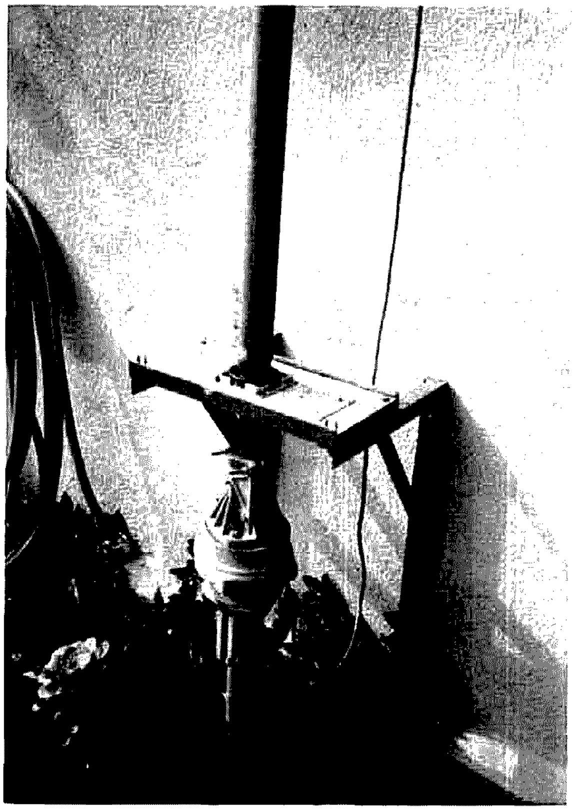


Photo 2. Lower support: the shelf.

joining the triangles

At this point you have two triangles bolted to the outside wall of your garage. The next step is to join them, using two pieces of the same angle iron. One piece should join the outer ends of the triangles, and the other will be several inches closer to the wall, depending on just where the mast will come. It should be midway between these two crosspieces. Having located both pieces, and drilled them and the upper leg of the triangle to accept 1/4-inch bolts, secure them in place.

shelf assembly

You'll note that these two cross-pieces and the triangle legs to which they are bolted form a rectangle. Find a piece of wood about 3/4 or 1 inch thick and

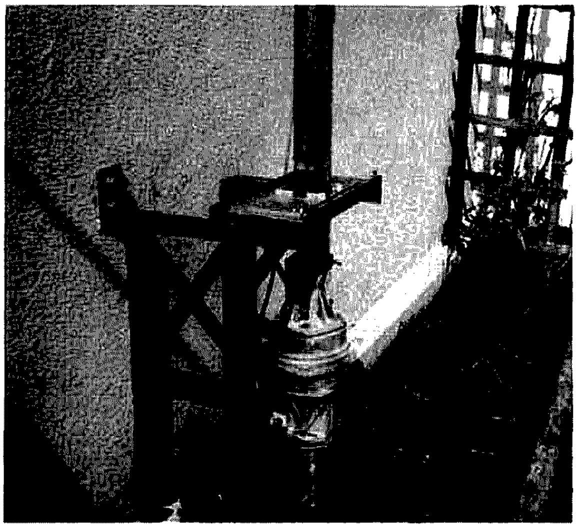


Photo 3. Lower support viewed from different angle.

cut it to lie inside this rectangle. Then find a piece of aluminum about 1/8 inch thick to go on top of it. (I used marine plywood for the wood, but a solid piece would do just as well.) This assembly — the pieces of aluminum and wood — will form the actual shelf. Drill them for mounting with 1/4-inch bolts, but don't assemble them yet. With the two pieces clamped or bolted together, mark the center by drawing cross lines from the corners. This is where the bearing will rest. You'll need to drill a hole through both pieces that's large enough to clear the inner race of the bearing, and any ham who has had to make a hole for a meter can cope with this. One precaution: make a small pilot hole through both pieces first. You may find that a large socket-hole punch will do for the aluminum, and an expansion bit for the wood.

bearing placement

Once you've made this hole, you can mount everything but the bearing. Center the bearing over the hole and mark around the circumference of the bearing with a pencil. You'll need to devise something to make a "fence" around the bearing to hold it in place. I used some 1/2 x 1/2-inch aluminum angle stock I happened to have. Almost anything will do, so use your imagination. You can use small machine screws to fasten this fence to the shelf; there's little strain on it. When it's complete, the bearing should drop neatly into the hole.

When the bearing is in place, lean over and sight down through it to the earth beneath and mark the spot with a chip of wood or some other marker. You may want to drop a plumb bob down to mark this spot; it's where the lower pipe on your rotor will enter the earth.

Your next job is to dig a square hole about a foot deep with this point at the center. You can also prepare the length of pipe by drilling holes through it at a point which will be well below the surface of the earth. Run some long bolts through it, leaving them so they extend a couple of inches on either side of the pipe. Two or three of these should do nicely.

What will happen, you ask, when you get the mast, the various pieces of pipe, the bearing, the rotor, and everything else set up on the shelf? Answer: *it will all fall over*. To prevent this, you'll need an upper support, located directly above the shelf and as high on the wall as you can get it. Perhaps "support" is the wrong word, since it doesn't bear any load. All it does is hold the mast in a vertical position and allow it to rotate within a loose collar.

wall-to-mast structure

Install a piece of the angle iron horizontally on the wall, bolted between the same pair of studs as the shelf. Then put the mast up temporarily and make sure it's in a vertical position (use a spirit level). You'll probably need a helper to make sure the mast stays in this position while you measure the distance from the wall to the nearest edge of the mast.

Now, using the leftover pieces of angle iron, you'll need to assemble a rectangular structure as deep as the distance from the wall to the mast. It needn't be as wide as the distance between the studs; mine is only 8 inches wide. It must be wide enough, however, to accept either a band bent to go around the mast, or perhaps a large U-bolt. It should be braced corner-to-corner so that it retains its shape, and further braced by two supports running from the rectangle down to a point on the wall. These last two supports may be pieces of the 1-inch strap iron, suitably bent in your vise, and bolted to the wall. These bolts needn't go through the studs, but remember to put those large fender washers on the inside.

erecting the mast

Now put the mast up on the fittings you've made. Clamp the rotor to the pipe extending below the bearing. Clamp the other piece of pipe to the lower part of the rotor. Mix up some cement and pour it into the hole below the rotor. Go inside, wash your hands, and find yourself a good book that will take you a couple of days to read while the cement cures.

guying

When the curing process is complete, you may want to shovel some dirt back over the top of the cement block. You'll then be ready to install the antenna on the topmost section of the mast. At this point, you'll probably recall that your mast was supplied with a set of guy rings — one to fit atop each of the larger sections. In large part, whether you'll use any at all

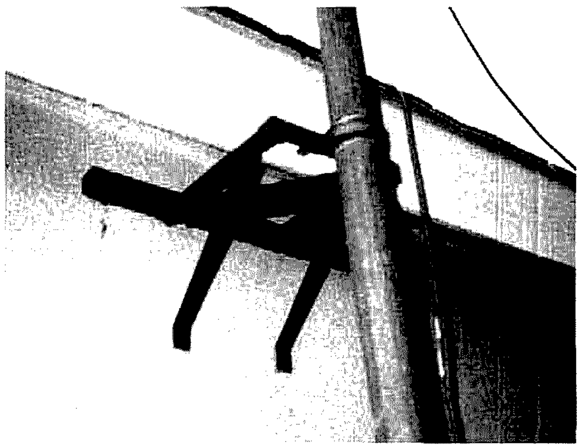


Photo 4. Upper support.

will depend on how high your mast is, how much support you can give it at the bottom, and whether experience has told you if you're likely to have a wind problem.

Consider the matter of support at the bottom. My lower installation is on a planter, but yours may be at ground level. Although I had eaves to contend with, you may have none. If your installation allows positioning your lower shelf close to the ground and your upper support near the top of the wall, you may have 7 feet or so between the bearing and upper support. (I have 4.) If there are no eaves to force you to extend your structures away from the wall, they'll be more rigid; you may be able to avoid guys entirely.

In my case I thought it best to have a set of guys at the bottom of the topmost section of the mast. Hams traditionally have followed the practice of using three guys spaced 120 degrees apart. However, the guy rings supplied, for reasons known only to the manufacturer, have four holes spaced 90 degrees apart, and a fifth hole midway between two of the others. It appears not to matter. Just use what you can, and don't tighten the guy wires as if they were violin strings. Remember, the mast is going to rotate inside that guy ring, so leave a bit of slack in the wires.

installing the antenna

At last you're ready to install the antenna atop the mast. I certainly wouldn't advocate installing a monster with a 30-foot boom, but I used to have a tribander on the mast, and all went well. My present antenna is a 10-meter monobander. Just raise that upper section to about eye level, mount the antenna on it when you get it clamped off, and do whatever final work is necessary while standing in reasonable safety and comfort on your roof.

Once the antenna is mounted, you'll have the task of extending the mast. Let me repeat my warning —

wear heavy gloves! As you push the mast up, you'll find that by pushing the section to one side a bit, it will bind enough so that you'll have a momentary respite and will be able to change the position of your hands.

Remember those marks you made on the mast sections for later reference? Now they'll prove their value. When you get the top section fully extended, clamp it off securely. If you're using the guy ring at this position, be sure to attach the wires to it before you raise it out of reach. If you have doubts about the efficacy of your clamp, you may even want to drill through the overlap between the two mast sections and secure them with a 1/4-inch bolt, flat washers, and a lock washer.

The higher you raise the mast, the less secure it will seem. *Don't worry.* Even though what you're lifting does indeed get heavier (because there's an extra section of mast each time, and the lower sections are larger and therefore heavier than the upper ones), you'll find that the load is well within your capacity. Of course, if you want to be doubly sure, ask a friend to hold the mast while you take a breather, search around for the pliers or wrench you've dropped, or just stand back and admire what you've wrought.

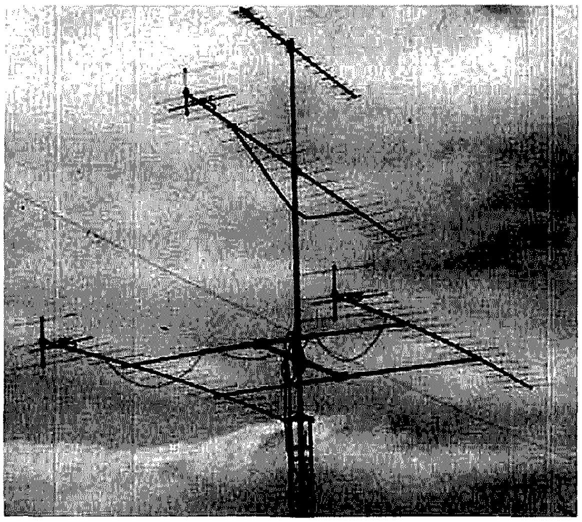
final precautions

One last thought: if you live in an area where the climate is less benign than it is here in Southern California, you may want to consider some sort of protection for the bearing assembly *before* you mount the mast to the nipple. The protective device will likely need to be attached, in some fashion, to the lowest section of the mast. Some sort of clamp or machine screws, with holes suitably drilled and tapped, can be used to secure it to the mast.

ham radio

Yagi triangular array

Somewhat unconventional stack performs well mechanically and electrically



Inspired by recent articles on stacking Yagis, I decided to improve my 2-meter antenna system, which consisted of a single 19-element, horizontally polarized Yagi. Before long, I had installed another 19-element antenna above it — and with great anticipation, began making comparative checks with the new system.

Because my primary interest is in terrestrial communications, the 2.5- to 3-dB increase in gain didn't overly impress me. With a 2 x 2 array in mind, I bought two more antennas and started designing an H-frame structure. Very quickly, however, I realized how large and heavy the completed array would be. I weighed the possibilities: a tilt-over tower, with block and tackle, would allow access to the array, but would probably be unfeasible because of the antennas' size and weight. After much soul searching, I decided that a stack of four antennas, with the required H-frame, would be out of the question.

alternate stacking methods

I have, from time to time, heard mention of the diamond stacking configuration and claims of improved performance when compared with conventional rectangular stacking. Assuming reports on the diamond's performance to be correct, and seeing a triangle as half of a diamond, I concluded that a triangle would be likely to offer better performance than an inline stacked array.

Unfortunately, oddball stacking geometry such as the triangle or diamond has received little or no publicity; I've yet to find informative literature on anything but the inline stacking methods. (It would almost seem that the numeral 3 simply doesn't exist in the world of antennas. Instead, the philosophy of "double or nothing" seems to prevail.) Nevertheless, after due consideration of weight distribution on the mast and tower, I concluded that a triangle stack configuration — with two horizontally stacked antennas located at the lower level of the mast and a third Yagi mounted at the top of the mast — would best suit my needs.

Theoretically, three Yagis would provide an additional 1.75-dB gain over a pair. Subtracting the phasing harness loss from the theoretical value, a realistic gain of 4.5 dB over a single antenna should be possible. What was more important to me at this time, however, was what the plotted antenna pattern would be. How would it differ from a rectangular stack of four antennas?[2] The only way to find out would be to build the triangular array and compare the results with published articles on a four-antenna array.

optimum stacking distances

The first problem was to determine the optimum spacing required between antennas. Available stacking data apply only to a pair of antennas stacked in either of two unique locations with respect to each other. Both antennas must be located on the axis of either the E or H plane. Polarization and phasing of both must also be the same.[1,2] With triangular stacking, the two lower antennas would satisfy the above con-

John C. Cichowski, W2IKP, 167 Emeline Drive, Hawthorne, New Jersey 07506

ditions. However, the upper antenna is offset, and its H plane axis does not fall upon that of either of the two below. Consequently, the spacing from it to either of the two below will differ from dimensions found in previous studies.[1,2] After a little head scratching, it became apparent that non-standard H plane stacking dimensions were still useful.

Visualize, as in **fig.1**, a pair of vertically stacked Yagis evolving through positions into a horizontal stack. For example, by keeping the lower antenna location and polarization fixed, and swinging the upper one through an arc (which defines a locus), while maintaining the same polarization as the lower one, one ends up with a horizontal stack. Each and every point along the locus will locate the movable antenna at an *optimal* distance from the fixed antenna. Also, at some point along the locus, the antenna will be equidistant to either of the two lower antenna positions (see **fig. 1**).

E and H optimum spacing differs

If optimum spacing for E and H plane were identical, the locus would be a 90-degree arc of a circle, with its radius equal to the optimum spacing dimension. However, the E and H plane optimum values are *not* equal, and studies have shown that optimum spacing, in a particular plane, depends on beamwidth in that plane. The greater the beamwidth, the closer the

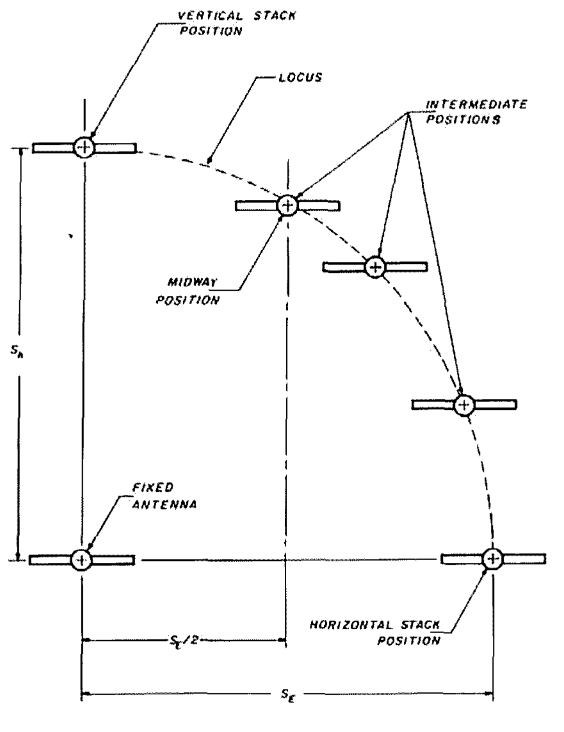


fig. 1. Vertical-to-horizontal stack orientation.

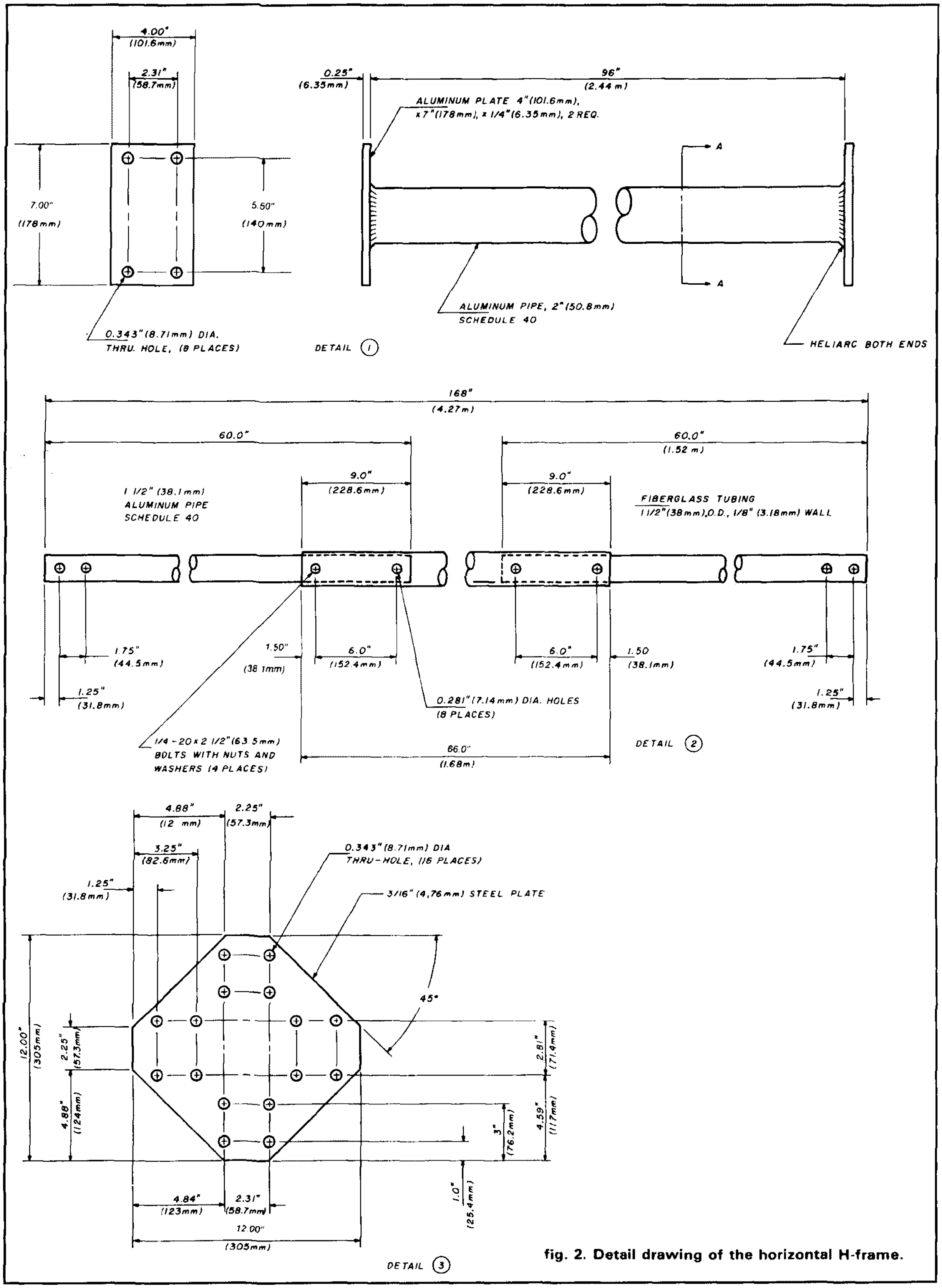


fig. 2. Detail drawing of the horizontal H-frame.

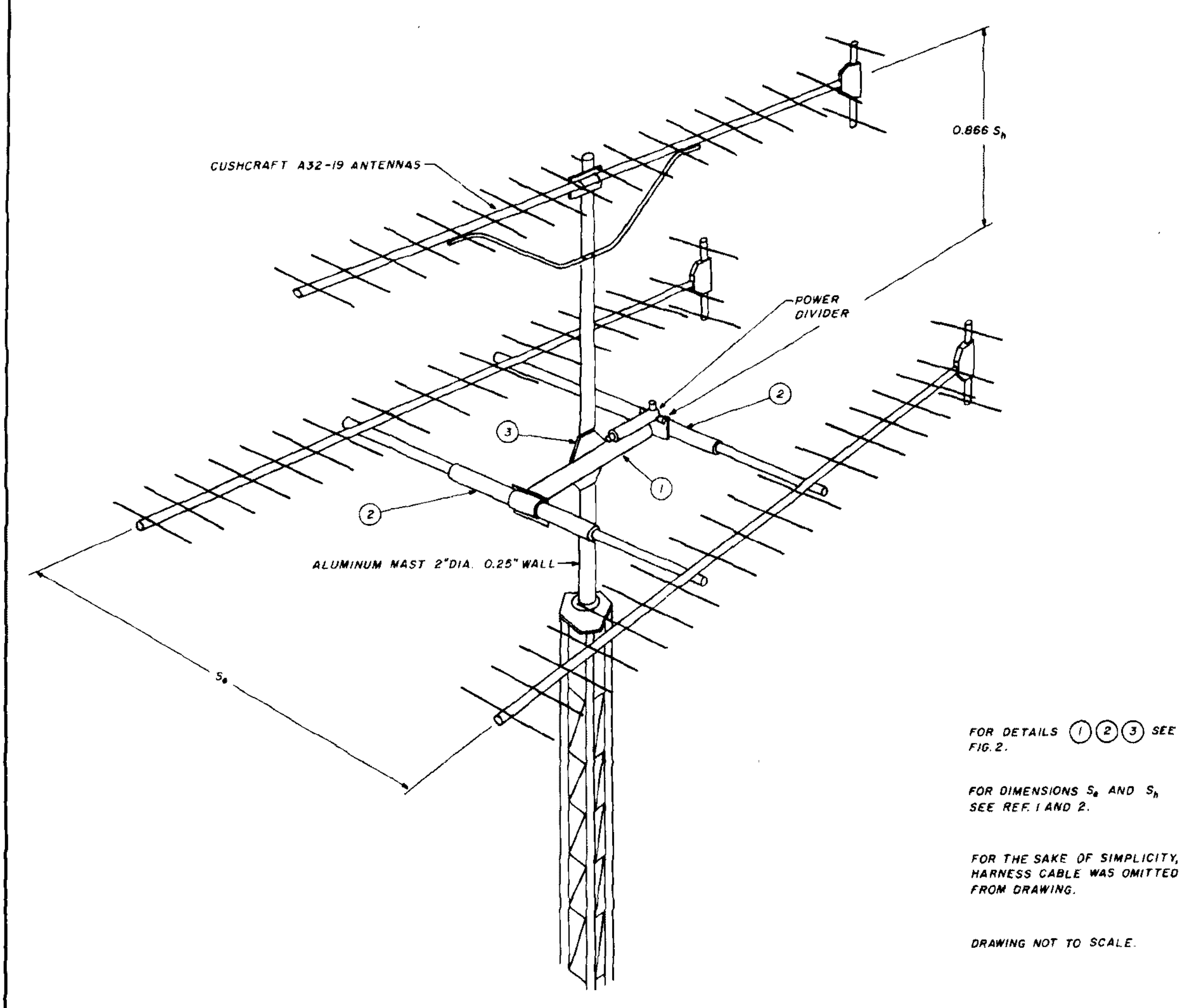


fig. 3. The Yagi triangle.

spacing.[1] The one feature all Yagis seem to have in common is greater beamwidth in the H plane than in the E plane. Consequently, H plane spacing will be less than the E plane's. The locus in this case is an arc of an ellipse. *(To visualize an ellipse, picture a hoop rotated about its diameter and viewed at an angle.)* Put into usable terms, E plane spacing is the value recommended by Joe Reisert, W1JR[1] and Steve Powlishen, K1FO.[2] Their tabulated data includes the most popular antennas in use today. The vertical stacking dimension is 86.6 percent of the optimum H plane dimension or $S = 0.866\ S_H$ where S_H is the optimum H plane stacking dimension recommended for inline stacking.[1,2]

horizontal H-frame construction

Horizontal stacking of horizontally polarized antennas requires the use of dielectric material in the immediate vicinity of the Yagi elements. A minimum distance of 1/2 wavelength of metal-free structure is recommended, or 1/4 wavelength beyond the active element tips.[3] Detail drawings for the structural parts used to assemble the H-frame are shown in **fig. 2**. The Cushcraft A32-19 antennas used in the Yagi triangle normally require boom supports supplied by the manufacturer; these are not necessary when mounted on this horizontal H-frame. The upper antenna, however, must be mounted in accordance with the manufacturer's recommendations (see **fig. 3**). Within reasonable limits, variations in frame design are certainly permissible.

If antennas other than those shown are used, changes in the overall length of items 1 and 2 might be required. Should it be necessary to make such adjustments, remember that the fiberglass support arms of the H-frame must be located midway between

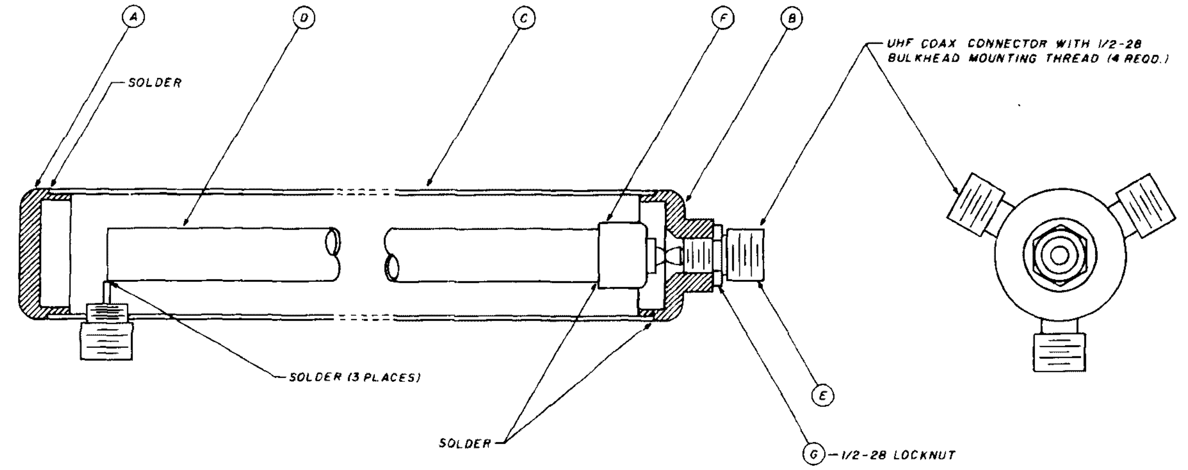


fig. 4A. Sectional view, 144-MHz three-way power divider.

the director elements of the antennas as shown in **fig. 3**.

material sources

I made use of readily available material. A local metal fence supply dealer stocked aluminum pipe and was also equipped with Heliarc welding facilities, which became very useful while constructing the H-frame. The 1-1/2 inch diameter fiberglass tubing, available in 5-foot lengths and used for satellite antenna work, was purchased from my local Amateur Radio dealer.

Because the inside diameter of the 1-1/2 inch aluminum pipe measures slightly more than 1-1/2 inches, it was necessary to shim the fiberglass tubing with glass filament tape to achieve a tight fit. The assembled frame and the three Yagis mounted on top of the tower are shown in **fig. 3**. All that remained at this point was choosing a feedline and deciding on a power divider method. A 50-ohm impedance, 7/8-inch hardline had already been installed with the previous array. The phasing harness and feedline around the rotator used more flexible RG-8U.

Use good quality cable for the harness. Each leg must be cut to equal electrical lengths, preferably from the same run of cable. Each antenna must be parallel to the others — elements as well as booms — and the most forward director element of all three Yagis must be located within the same vertical plane. Otherwise, the wavefront launched by any one individual antenna will be out of phase with the others, resulting in lower gain, greater sidelobes, and possible multipath propagation. Phasing lines, besides being equal in length, should be kept as short as possible, especially at higher frequencies. Mounting the power divider as shown in **fig. 3** allows shorter harness leads.

three-way power divider

Obtaining a three-way power divider meant building one from scratch, because I couldn't locate any commerical units. So I went back to the books and set off on a thorough search of local supply houses for appropriate hardware.

To my knowledge, two methods for power splitting are commonly used. Most popular is the transformation of impedance by the use of a single 1/4 wavelength of coaxial transmission line. A common input port is located at one end and the required number of output ports at the other end. The characteristic surge impedance is determined as the mean value between transmitter output impedance and the parallel combined load impedance presented by the three antennas. Manufacturers of communications equipment have standardized their products for use with 50-ohm coaxial line. This simplifies the mathematics to determine power divider impedance when using more than one Yagi. Reduced to its simplest form, the equation for characteristic surge impedance for the above power divider becomes:[4-8]

$$Z = \frac{Z_O}{\sqrt{n}} = \frac{50}{\sqrt{n}} \qquad (1)$$

where n = number of antennas in array, Z_O = impedance of each antenna and equals the transmitter output impedance of 50 ohms.

Using **eqn. 1**, the characteristic impedance is:

$$Z = \frac{50}{\sqrt{3}} = 28.9 \text{ ohms}$$

To determine the proper diameter ratio for coaxial line

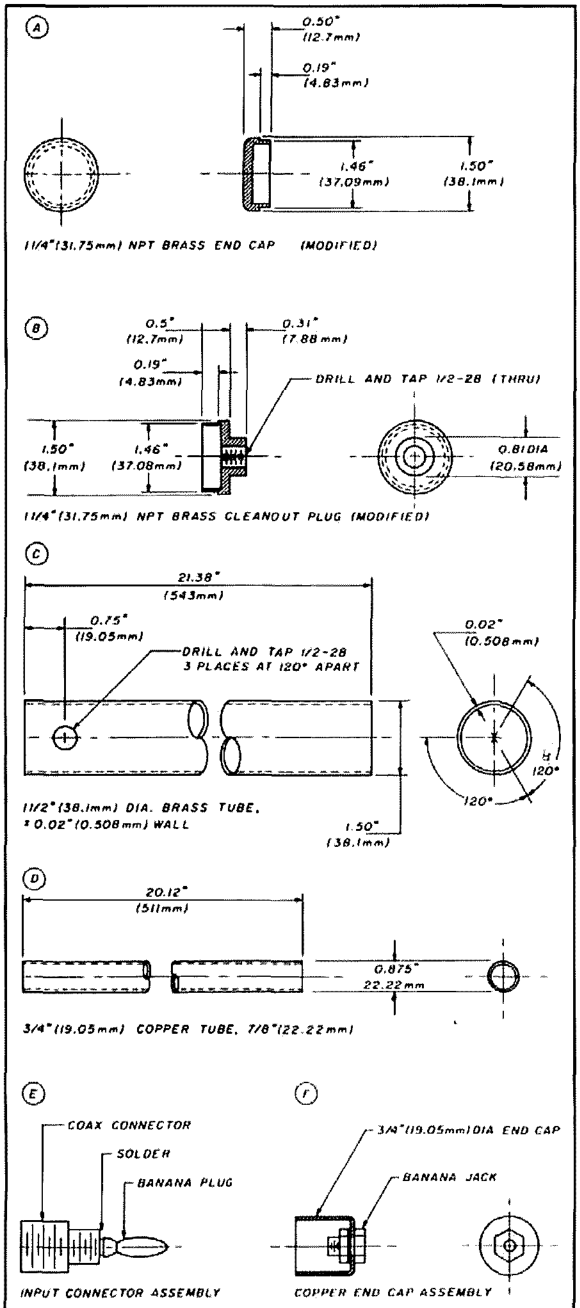


fig. 4B. Details of 144-MHz three-way power divider.

with the above impedance, the following relationship is used:

$$a/b = antilog \frac{Z}{138} = 1.62 \qquad (2)$$

a = Inside diameter of outer conductor
b = Outside diameter of inner conductor
Z = Characteristic surge impedance of coaxial line in the power divider.

The above diameter ratio (a/b) can be closely satisfied by using standard 3/4-inch diameter copper plumbing tubing (which actually measures 7/8 inch diameter) and 1-1/2 inch diameter brass tubing with 0.02-inch wall, normally used for kitchen sink drains. It can be purchased without the usual nickel plating at most plumbing supply stores.

To cap each end of the 1/4-wavelength line, it's necessary to machine 1-1/4 inch NPT brass cleanout plugs and end caps to the dimensions shown in the detail and assembly drawing for the three-way power divider (**fig. 4**).

Suitable connectors for this application are the familiar UHF type with 1/2-28 thread mounting capability. Amphenol 83-875 or equivalent can be used. By removing the snap ring, the connector can be dismantled and soldered to the body of the divider. Otherwise, excessive heat will destroy the insulator insert. To simplify assembly, it was necessary to include what at first would seem to be two unnecessary steps: first, the addition of a banana plug and jack at the input end of the line, to allow for adjusting the position of the inner conductor when you're soldering to output ports; and second, the drilling of three tapped holes (1/2-28) at the output end to hold coax connectors in place while you solder them to the 1-1/2 inch diameter brass tubing.

The power divider shown in **figs. 5** and **6** is the 432 MHz version of the above. Also, a scaled-down H-frame for a 432-MHz Yagi triangle is shown in **fig. 7**. (Although the antennas shown aren't representative of 144-MHz proportions, the reader may find the photos helpful nevertheless.) For further harness detail, see **fig. 8A**. The alternate power divider method (**fig. 8B**) requires 86.7-ohm impedance transformation sections of coaxial line in each leg of harness to the antennas.

$$Z = Z_0\sqrt{n} \qquad (3)$$

A 1/4 wavelength of RG-62/U cable whose impedance is 93 ohms should work well. However, transmitter power must be limited to a couple of hundred watts. With higher power, use of RG-63/U is recommended. The velocity factor for both cables is 86 percent, which makes the overall length (including connectors) of the 1/4-wavelength sections 17 inches.

A three-way "T" junction must be used at the feed point. A weathertight metal junction box with closely spaced coaxial connectors will easily satisfy the short junction lead lengths required at the distribution point. A variation of the above division method is shown in **fig. 8C**. The three 1/4-wavelength sections as well as the three 50-ohm harness cables are replaced with equal lengths of RG-62/U. The three lengths, however, must be odd multiples of 1/4 wavelength each.

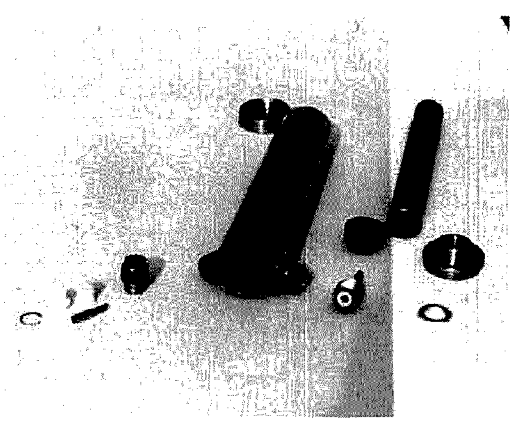


fig. 5A. Three-way power divider before assembly.

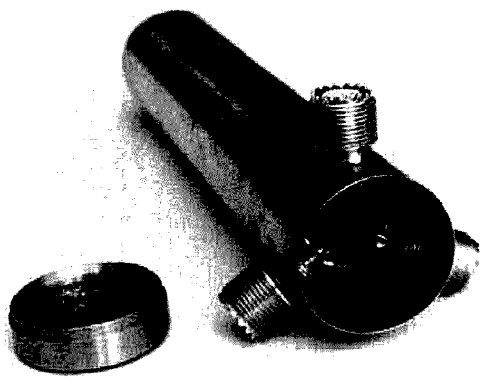


fig. 5B. Three-way power divider output ports.

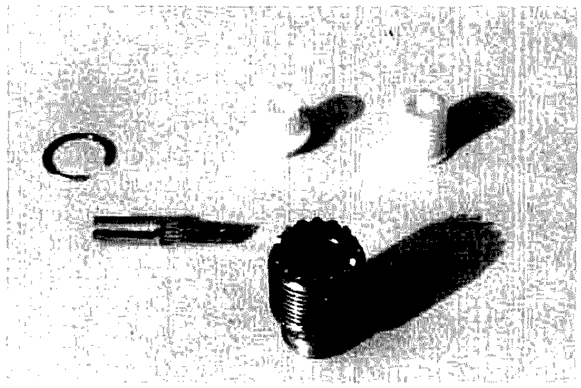


fig. 5C. Dismantled Amphenol coax connector.

Before connecting the harness to the power divider, best results will be obtained if each antenna is separately adjusted for best SWR using that leg (i.e, the same length) of feedline intended for the harness.

After adjustments have been made, connect the power divider to the antennas and feedline. Measure the SWR of the assembled array. In some cases, the

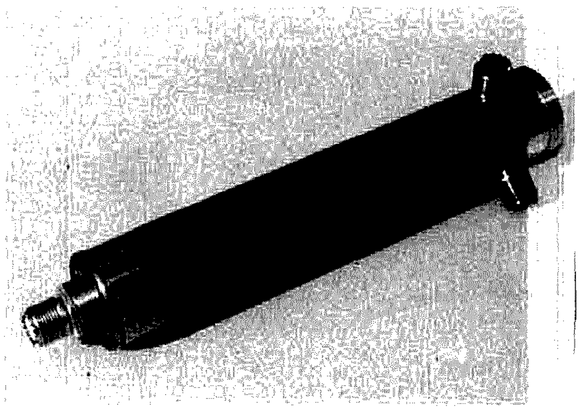


fig. 6. Assembled three-way power divider.

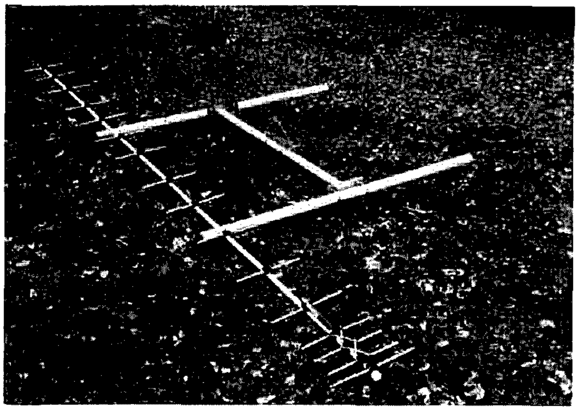


fig. 7. Horizontal H-frame for 432-MHz Yagi triangle.

final SWR measurement will appear to be better than that of the individual Yagis. Offhand this would seem to indicate an improvement to the system; however, this may not necessarily be so since the SWR measurements, other than 1:1, simply indicate the presence of a reactive load. The reactance, which can be either inductive or capacitive, depends upon how far the operating frequency is from the center frequency of the antenna and on the adjustment of the matching device at the individual antennas.[4] The inductive reactance of one antenna can cancel out, in part or completely, the capacitive reactance of another so that the resulting sum can be less than that of the individual antenna. Other than becoming more broadband (i.e., having lower Q), this does not imply that gain performance of the stacked array will be enhanced in any way. The SWR, as previously measured at the *individual* antennas, still exists and should be adjusted for the lowest ratio attainable or the maximum forward gain will be degraded accordingly. Once assured that the individual as well as the overall system SWR measurements are satisfactory, the Yagi triangle is ready for use.

E plane plot

The E plane plot shown in **fig. 9** indicates a half-power, 15-degree beamwidth. This was determined by the 48.5-percent method described by Gunther Hoch, DL6WU.[2] A comparison of the E plane plot of four stacked NBS-17 antennas with that of the Yagi triangle shows very little variation.[2] In fact, the front-to-back response seems to be better with the triangle. This might be attributed to the trigon reflectors on the Cushcraft A32-19 antennas used in the Yagi triangle.

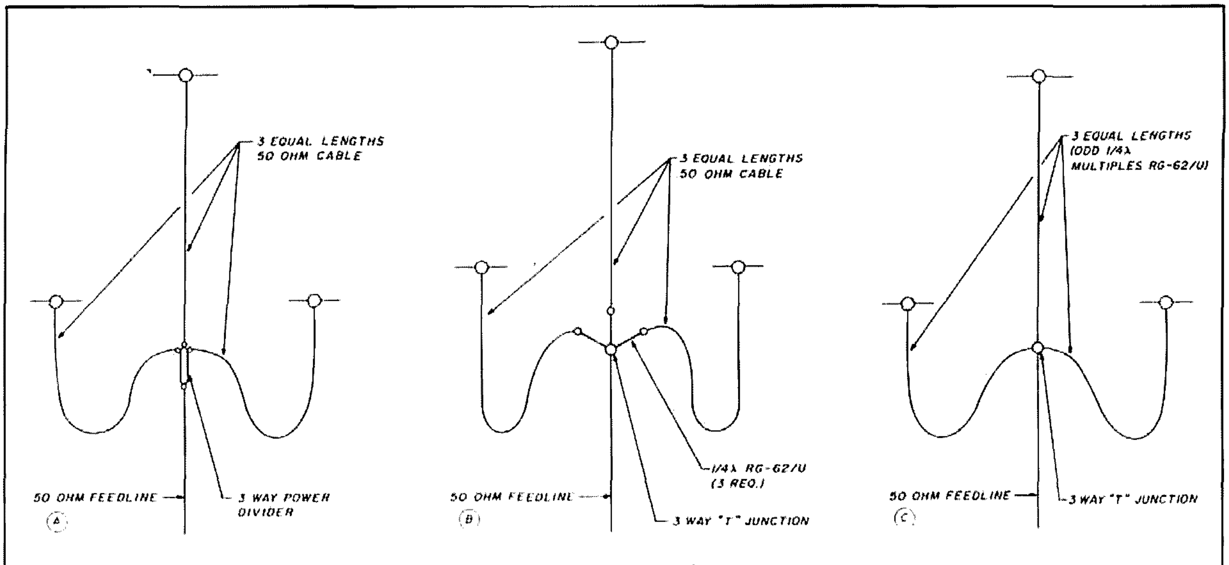


fig. 8. Alternate power divider and harness methods.

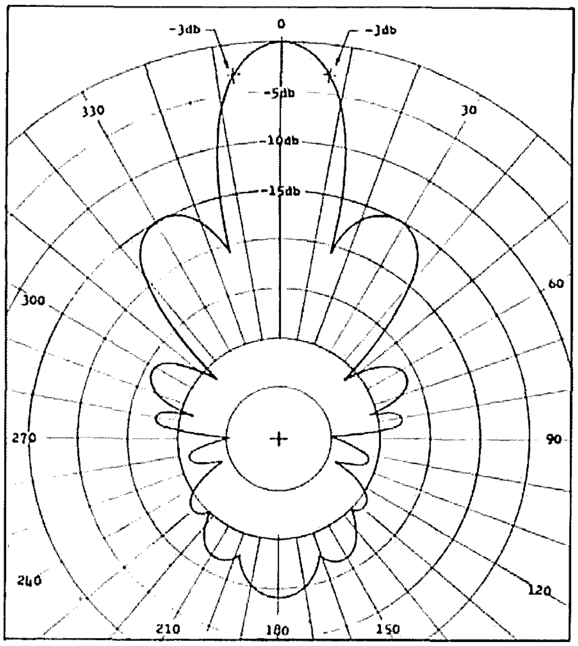


fig. 9. E plane plot.

No attempt was made to plot the H plane pattern, since no facilities to do so were available. It's my guess that the pattern would very much resemble that of two vertically stacked A32-19 antennas. Since I expect to duplicate the Yagi triangle at higher frequencies in the near future, a smaller array will be more manageable for the setup required to make H plane measurements.

antenna rotators and resolution

As the gain of a beam antenna system is increased, the beamwidth gets smaller until the point at which the resolving capability of the rotating system reaches a practical limit.

Most rotators available for Amateur use are geared to rotate at 1 rpm. The indicator on the control unit is graduated in divisions of 5 degrees. This means that rotation occurs at a rate of 6 degrees per second, or to put it in more dramatic terms, *less than one second per division*. A 15-degree segment (three divisions) will be scanned in 2.5 seconds.

To fix a beam heading, the antenna rotation between first nulls on either side of the main lobe shouldn't take less than 5 to 6 seconds. A main lobe with 15-degree beamwidth will have approximately 30 degrees between first nulls. Therefore, 1-rpm rotators will perform at the limit of their resolution capability. Antennas with beamwidths less than 15 degrees should be rotated with slower-speed devices. Aircraft prop-pitch motors are often used for this purpose. Manufacturers of one or two commercial rotators available for Amateur use claim dual speed, but the load capability of these units isn't sufficient for the size

of the 144-MHz antenna array that would require the lower speed.

Used with 1-rpm rotators, antennas with less than 15-degree beamwidth require rocking the rotation back and forth several times to attain true beam heading. The problem is further compounded because of play (backlash) inherent in all such devices.

Still another resolution gremlin is the inertia that builds up during antenna rotation, causing long-boom Yagis to whip laterally when rotation is suddenly stopped. Many of these antennas have boom braces to keep them from sagging. However, the brace does little or nothing for the side motion. Heavy gusts of wind will also cause lateral flexing with these antennas. Though the two lower antennas of the Yagi triangle aren't prone to this problem because of the H-frame construction, the upper antenna does occasionally do a little dancing. Polypropylene guys from the upper antenna to the H-frame should remedy this problem.

Rotation at 1 rpm seems like a long enough period of time for a complete 360-degree turn of the antenna, and many of us — myself included — wouldn't relish the thought of extending the time. Therefore, antenna arrays with beamwidths of 15 degrees, or perhaps by stretching a point or two, even 14 degrees, should satisfy the resolution capability limits of 1-rpm rotators. This Yagi triangle is such an antenna.

performance

The triangle-stacked Cushcraft A32-19 antennas certainly perform better than the original dual stack. The theoretical 1.75-dB increase in signal seems to mock the theoretical 3 dB originally obtained while using the dual stack. QRP signals, unheard before, are now Q5 copy. Reports on my signal are almost always complimentary.

Raising or lowering the tower with the triangle stack is a one-man operation. Repeated inquiries about the triangle stack seem to indicate that others would like to give it a try. Anyone interested in a totally different approach for stacking Yagis will find building the Yagi triangle a worthy and rewarding effort.

references

1. Joe Reisert, W1JR, "VHF/UHF World: Stacking Antennas — Parts 1 and 2," *ham radio*, April and May, 1985.
2. Steve Powlishen, K1FO, "Stacking Yagis is a Science," *ham radio*, May, 1985.
3. American Radio Relay League, *The ARRL Antenna Book*, 13th Edition, pages 75, 129, and 245.
4. William I. Orr, W6SAI, *Radio Handbook*, 17th Edition, page 459.
5. W. M. Meyer Jr., W6GGV, "Transmission Line Circuit Design," *ham radio*, January, 1981.
6. Frederick E. Terman, *Radio Engineers Handbook*, First Edition, page 174.
7. Jim Pruitt, KL7HIT, "Easy Matching Sections," *ham radio*, March, 1982.
8. Frank A. Regier, OD5CG, "Series Section Transmission Line Impedance Matching," *QST*, July, 1978.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

ham radio techniques

In the northern areas, winter is almost over and signs of spring are in the air. It's a good time to think about antenna systems. A lot of interesting antenna concepts have just been waiting for some good weather to set in! Here are some interesting projects for you to consider . . . .

inexpensive base station antenna for 2 meters

I think Fred Dietrich, NM6J, has come up with a winning 144-MHz antenna that has decent gain and a low SWR, and costs very little to construct. Shown in **fig. 1**, this vertical, omnidirectional array is only about 6 feet tall. The antenna structure is made of a length of 3/4-inch Schedule 40 (thick wall) PVC water pipe. The overall pipe length is long enough so that the antenna can be supported by clamps at the base end. For this particular installation, an 8-foot length of PVC was selected. The top of the pipe is closed with a PVC cap cemented in place using the liquid sealer that applies to such material.

The radiating portion of the antenna is a No. 12 copper wire 51.75 inches long. Enough extra wire is added to this length to allow it to be attached to the cap with PVC cement and to form a solder connection to the coax line at the base of the antenna.

Two phasing sleeves are used. They're made of galvanized hardware cloth folded around the PVC pipe and wrapped with wire to hold them in place. Each sleeve is 17.25 inches long. The retaining wires are soldered to the hardware cloth at several points around the circumference.*

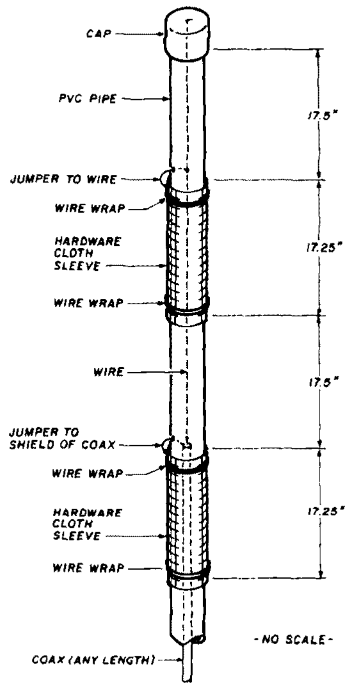


fig. 1. Two-meter PVC base station antenna.

A short jumper wire joins the top of the upper screen to the antenna wire running inside the PVC tubing. It is suggested that this wire be soldered to the antenna wire and then fished out through a small hole drilled in the PVC wall. If this and the following step are done before the top PVC cap is fastened in place, the assembly will proceed smoothly.

A second phasing sleeve is affixed to the structure below the first, as shown in **fig. 1**. This sleeve is connected to the outer shield of the coax line by means of a short length of wire inserted through a second hole after the antenna wire has been passed within the PVC pipe. After assembly, the holes are filled with cement to make the assembly waterproof.

The antenna is mounted in a vertical position and the coax line is brought down directly below the antenna. A VSWR plot representative of the antenna's performance is shown in **fig. 2**.

a "rubber duckie" for 160 meters

The ham who lives on a small, treeless lot faces a real problem when contemplating 160-meter operation. One solution to this problem is a vertical antenna. But a quarter-wave vertical antenna on "top band" is over 130 feet high. Joe Moraski, KY3F, has a solution to the problem. He recommends a helix antenna operating in the normal mode — that is, a coil with a small diameter compared to the operating wavelength. Maximum radiation is *normal* to the axis, hence the name. This is the same mode of operation as that of the 2-meter "rubber duckie" antennas used on handhelds.

*Though more expensive copper-based hardware cloth would maintain its electrical properties longer. — Ed.

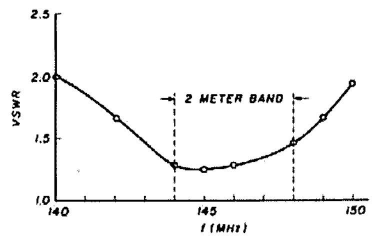


fig. 2. Measured performance of PVC antenna on 2 meters.

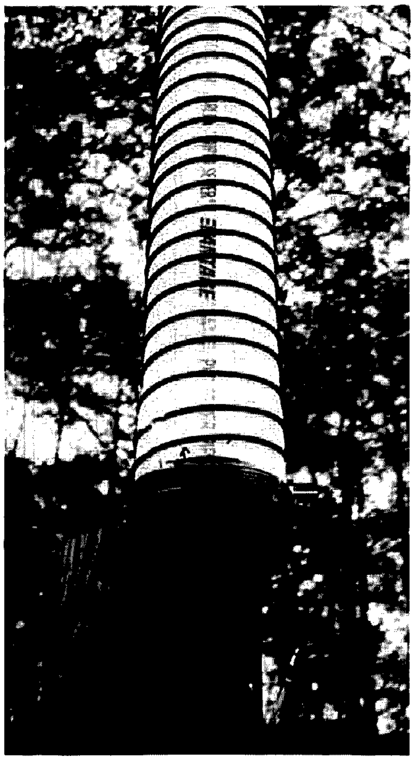


Photo 1. Base assembly of the KY3F vertical antenna for 160 meters. Final frequency adjustment is made by varying number of turns at the bottom of the helix.

There are no hard and fast rules about the length or diameter of the helix. The rule of thumb is that about a half-wavelength of wire is used to make the helix.

Antenna size is a matter of tradeoffs. The shorter and thinner the helix, the narrower the bandwidth. The longer and thicker it is, the harder it is to build and keep up in the air! A shorter helix is less efficient — consequently, the longer the better.

Since the helix bandwidth is narrow, a top hat is added to reduce antenna Q and add capacitance at the high voltage point. The resulting reduction in circuit Q causes the feedpoint impedance at the antenna base to vary less rapidly with frequency change than the unloaded antenna. This means that the antenna can be used over a larger portion of the band than would otherwise be possible.

By experiment Joe found that a 20-foot antenna was a good operating compromise. Accordingly, he used two 12-foot sections of 4-inch diameter PVC water pipe cemented together to make a 24-foot mast. He wound No. 18 insulated hookup wire on it at ten turns-per-inch spacing. This helix, in combination with a screen wire capacitance hat on top, resonated in the 160-meter band when operated against a ground rod and quarter-wave counterpoise wire run around the backyard. Four 30-foot radials were added. A sketch of the antenna is shown in **fig. 3.**

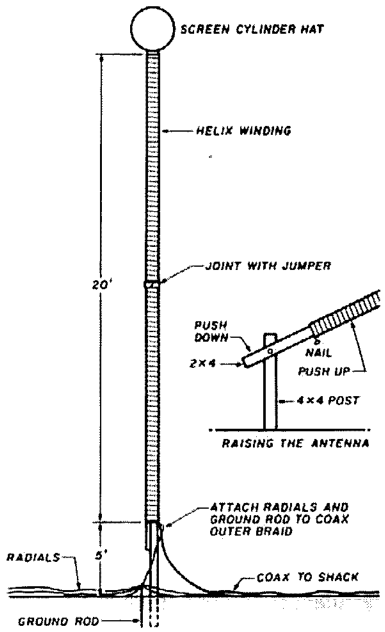


fig. 3. KY3F's 160-meter "Rubber Duckie."

The construction is simple if done in the proper sequence. The first step is to drill holes for the end tie bolts that terminate the winding. The holes are 10 feet apart. Galvanized bolts are used, with washers on each side of the PVC pipe. With a tape measure and felt-tip pen, make small marks at 1-inch intervals between the bolts.

Next, fasten an eye-lug to one end of a 140-foot length of No. 18 insulated wire. Fasten the lug to one bolt and wind the coil on the PVC pipe, using the pen marks as a guide — one turn per mark. Use tape to hold the coil in place as you progress along the form.

Wind the wire as tightly as you can and when you reach the second terminating bolt, cut the wire and place an eye-lug on the end that will fit over the bolt.

With the winding properly spaced, run a bead of RTV along the length of

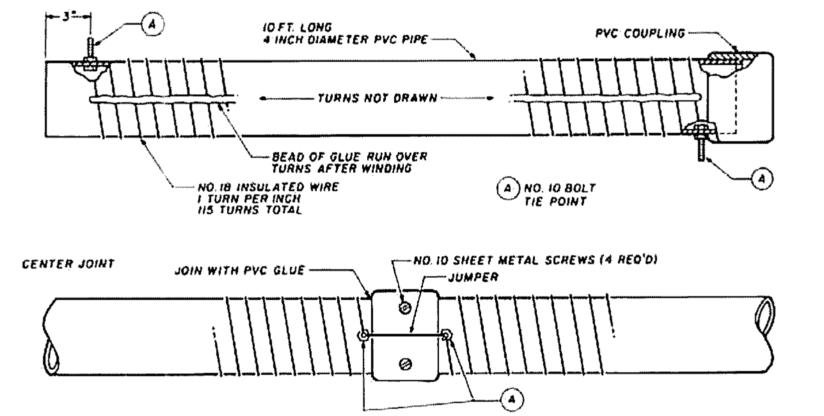


fig. 4. Mechanical details of the coil sections.

✓ 143

pipe over the coil turns to lock them in place.

You have now completed half the antenna. Now, wind a second similar coil on the second section of PVC pipe, making sure that both coils are wound in the same direction (left- or right-hand turns, but be sure they're both the same).

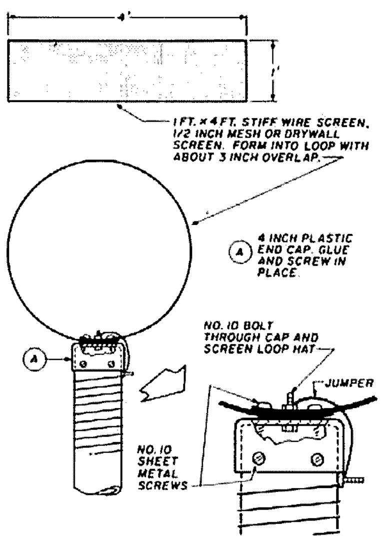


fig. 5. Top Hat assembly.

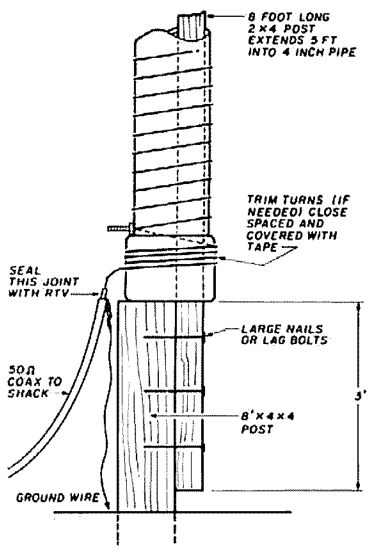


fig. 6. Mounting arrangement of antenna to post.

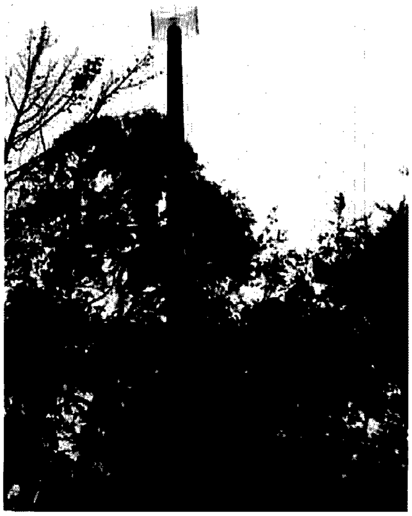


Photo 2. View of winding and capacitance hat on KY3F helix antenna.

The two pipe sections are now joined with a plastic pipe splice section and PVC cement. Align them quickly and let the joint dry (**fig. 4**). Some PVC pipes have a built-in coupling joint — nice if you can locate one. For added strength, run four No. 10 self-tapping sheet metal screws through the joints where the PVC pipes and splice section overlap. Finally, connect a wire jumper between the two coils to form one 20-foot coil.

The next step is to make the "top hat." A section of 1/2-inch mesh chicken wire or drywall screen can be used. Wrap it into a cylinder about 1 foot in diameter and 4 feet long. Solder the overlapping wires. Drill the cap piece of the antenna for a No. 10 bolt, which is bolted through the overlap portion of the top hat. Use large washers on each side of the screen to enhance stability. Then run four No. 18 sheet metal screws through the screen and cap to keep the screen from turning or buffeting in the wind (see **fig. 5**).

The final step is to attach the top hat to the top of the helix with a jumper wire. Glue the top hat in place and pass four sheet metal screws through the hat to hold it securely to the PVC pipe.

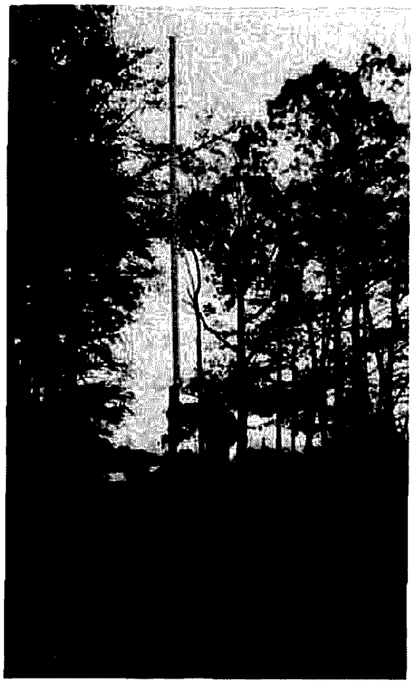


Photo 3. Joe, KY3F, standing beside his 160-meter "Rubber Duckie."

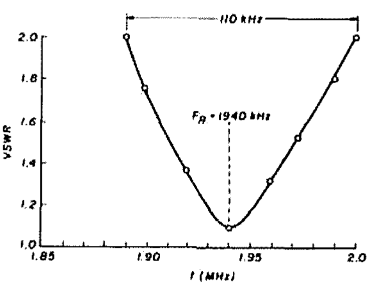


fig. 7. "Rubber Duckie" for 160 meters has 2:1 bandwidth SWR over 110 kHz. Antenna was adjusted for 1940 Hz.

Dig a 3-foot hole for the mounting post. Wrap the portion of the post that will be beneath the surface of the ground with heavy kitchen-type aluminum foil. A double wrapping held in place with plastic tape will protect the post from ground water. After the sides and bottom of the post have been wrapped, place the antenna in the hole and drive a ground rod into a corner of the hole, as far down as possible. Fill the hole with concrete, using a level to make sure the post is vertical.

To make the pivot joint, insert a section of 2x4 lumber within the PVC tubing. Fasten this extension to the 4x4 ground post with one lag bolt, used as a pivot. (See **fig. 6** for details.) Bolt the 2x4 and 4x4 together, with the 2x4 in a vertical position. Then raise the antenna to a vertical position and drop it down over the 2x4 section. When the antenna is in the final position, it will sit atop the 4x4 post with the 2x4 section acting as a positioning guide. Various views of the installation are shown in the accompanying photographs.

When completed, the radials and outer shield of the coax line are connected together and the inner conductor is connected to the helix by a short length of wire. The open end of the coax is taped and covered with RTV to keep water out.

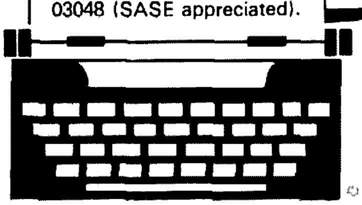
As shown, the antenna is resonant at the top end of the 160-meter band. Four close-spaced turns were added at the bottom of the antenna to bring the resonant frequency down to 1.94 MHz. By picking the part of the band you wish to use most and adjusting the extra turns at the antenna base, you can resonate the antenna at any spot in the band you wish. SWR plots of Joe's antenna are shown in fig. 7.

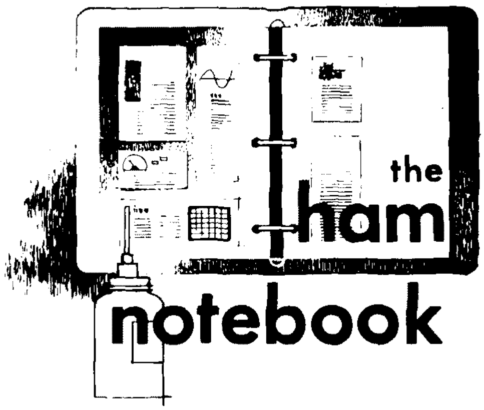
Joe says the helix seems stable without any guy ropes, but recommends that ropes be added if the antenna is in an exposed, windy location. Light nylon guys would do the job.

ham radio

Invitation to Authors

ham radio welcomes manuscripts from readers. If you have an idea for an article you'd like to have considered for publication, send for a free copy of the *ham radio* Author's Guide. Address your request to *ham radio*, Greenville, New Hampshire 03048 (SASE appreciated).





a 2-meter halo antenna

After obtaining a 2-meter multimode radio and operating it mobile for a short time, I came to a conclusion: 2-1/2 watts output and a 5/8-wave vertical wasn't good enough.

I decided to improve the antenna first; I could install my small 80-watt amplifier later for long trips. I decided to build a 2-meter halo since I'd worked several mobile stations who were using them, and they seemed to do a good job.

construction

The halo is a half-wave dipole bent into a circle (**fig. 1**). To make the insulator mounting block (**fig 2**), cut a piece of 1/2-inch thick plastic into a 2-1/2 by 3-inch rectangle. Cut a slot and drill the holes as shown in **fig. 2**.

The driven element or dipole is made from a 38-inch long, 3/8-inch diameter piece of copper tubing. Mark the center of the piece of tubing and bend it into a hoop measuring 12 inches in diameter. Drill a 9/64-inch hole at the top of the center mark on the dipole element. Secure the dipole element to the mounting block by inserting a screw through the dipole element and mounting block. Fasten with a lockwasher and nut. Insert a small piece of 5/16-inch diameter wood dowel into the ends of the halo element, leaving a 1-1/2 inch gap between the tubing ends. This completes the main element of the halo (see **fig. 1**).

To assemble the rest of the halo, refer to **fig. 3**. Mount the small plastic (*not metal!*) box under the insulator mounting block.

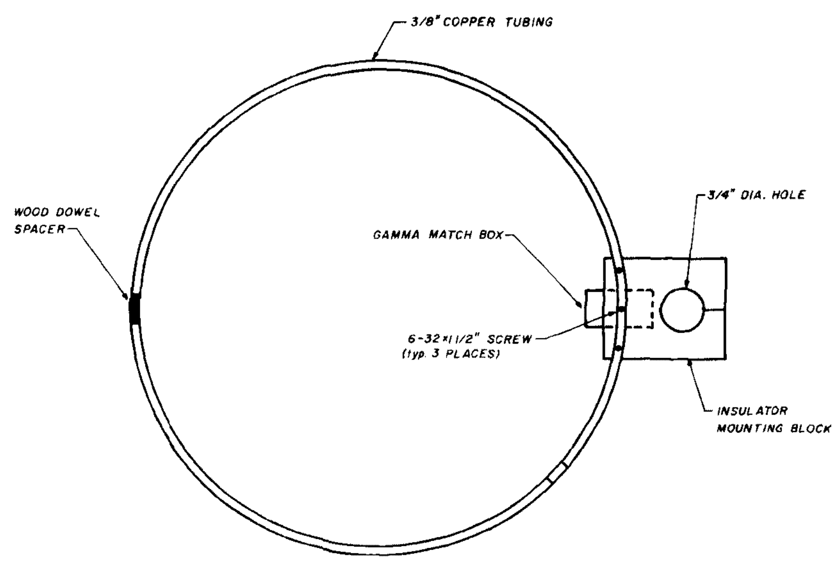


fig. 1. Top view of 2-meter halo.

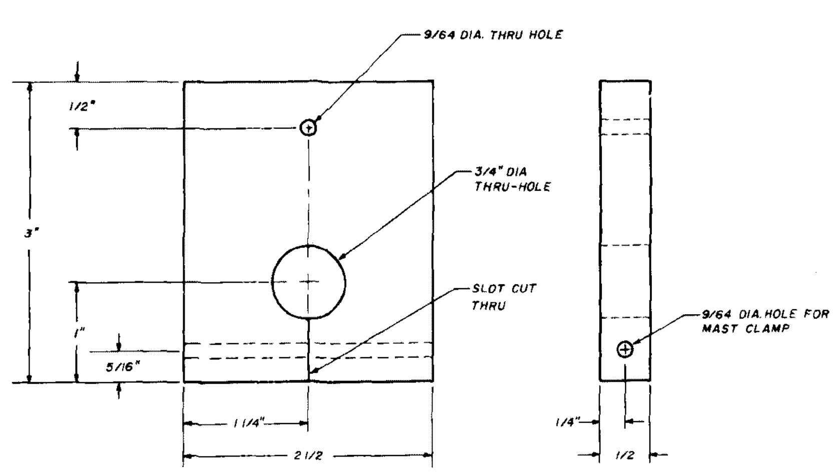


fig. 2. Insulator block details.

Following the details shown in **fig. 3**, drill the holes in the box and install the coax connector and gamma match capacitor. A variable capacitor of about 35 pF will work fine.

A 6-inch length of 3/8-inch diameter copper tubing is used for the gamma rod. Bend it around the halo's element to form it into a slight circle. Make a shorting bar now so you can secure the gamma rod to the halo antenna. (Any kind of easily bendable metal will work.) Be careful to keep the spacing between the gamma rod and dipole element to about 1-3/4 inch.

Insert one end of the gamma rod into the gamma match box and install the shorting bar on the other end.

Lay the halo on its side, with the open end of the gamma box facing up. Apply some 5-minute epoxy around the gamma rod and let it dry. Your halo is now finished and needs only to be tuned.

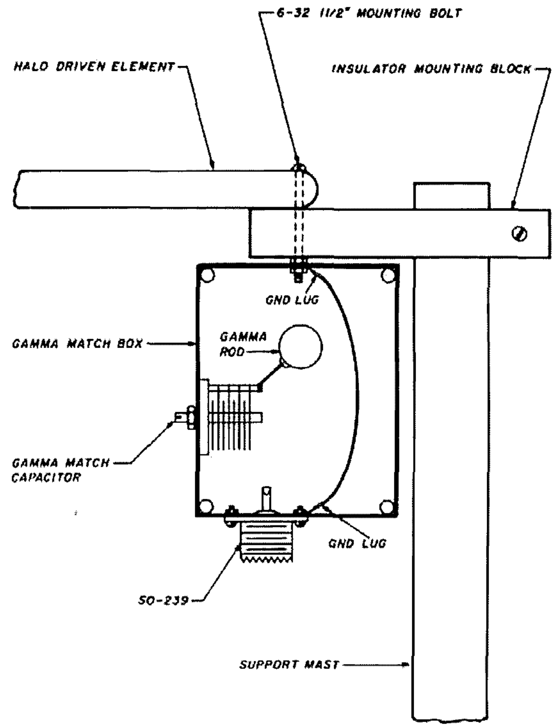


fig. 3. Matchbox details.

tuning

Mount the halo 5 to 6 feet above the ground or temporarily attach it to your car. Adjust the spacing on the driven element for minimum reflected-power indication. (Mine was lowest at an 11/16-inch spacing.) Do the same for the shorting bar, sliding it back and forth along the gamma rod. (My lowest SWR was 1 inch from the end of the gamma rod.) The final adjustment is made by tuning the gamma-match capacitor for minimum reflected power. My final SWR is 1.2:1 on the halo.

Remove the halo and seal the gamma match box. Plug the end of the gamma rod with RTV or epoxy. Coat the wood dowel spacer on the driven element with epoxy; this will waterproof it and keep it from slipping. The last step is to spray paint the assembly with a nonlead-based paint.

The 2-meter halo has increased my range significantly. While on vacation in Oklahoma, I worked West Virginia, New Jersey, and Maryland during an E opening. (My normal range is 50 to 100 miles with only 2-1/2 watts.)

One final word of caution: if you build and mount the halo, be prepared for lots of stange stares and questions. You'll get plenty of them.

Jerry Felts, NR5A

ham radio

short circuit

MMIC multiplier chains

In **fig. 5** of N6JH's article, "MMIC Multiplier Chains for the 902-MHz Band" (February, 1987, page 72), all values indicated as "μF" should be corrected to read "pF." Note too that coil L1, which can be seen just to the left of the crystal and directly above the partially meshed plates of the variable capacitor (**fig. 7**), is not the same as the coils in the multiplier. L1, which is five turns of No. 24 (AWG), is air-wound with an interior diameter of about 0.2 inches — this dimension is not critical because only broad resonance is needed to select the correct crystal overtone.

a no-compromise, multiband, low-VSWR dipole

Back-to-basics design uses capacitor divider/balun for high-efficiency operation

In searching for an effective, balanced feed system for a dipole, I developed an antenna that's efficient, exhibits low VSWR across several bands at the same time, and meets my original objectives. Patented under the title, "Dipole of Delight," its design is based on the use of a capacitive balun at the center of the dipole.[1,2,3]

The use of capacitors at the midpoint of the dipole allows the resonance currents in the dipole to reach larger amplitudes than are possible when the 50-ohm cable impedance is present as a series resistance. Apart from the copper loss, the principal limitation of resonant currents is the radiation loss. For this reason the capacitor dipole is highly efficient and has a very wide bandwidth.

Before studying the details, one should review the problems associated with the traditional half-wave dipole (see **fig. 1**), which are chiefly:

- an unbalance that causes an undesirable current on the outside of the shield results in higher levels of electrical noise from local sources on receive, and on transmit provokes annoying rf voltages at the transceiver (i.e., microphone feedback or finger burns); and
- matching problems between free-space impedance (377 ohms), a typical traveling wave on a wire dipole (800 ohms), and the feedpoint impedance of a half-wave dipole, said to be 73 + j 42 ohms.[4]

The first problem experienced with the conventional dipole has traditionally been solved by using a balanced feedline or a transformer balun. Unfortunately, use of a transformer brings its own problems: increased weight; the possibility of saturation and harmonic generation; or introduction of even more inductive reactance, from its leakage reactance, which necessitates shortening the antenna more than the customary 5 percent to achieve resonance.

The next step involves replacing the dipole with its equivalent (resonant) circuit as seen at its center where the voltage is least and the current is maximum. See **figs. 1, 2,** and **3**.

The magnitude of the various components are:

$$Z_o = \sqrt{\frac{L}{C}}$$

where Z_O = traveling wave impedance
where L = inductance per meter
and C = capacitance per meter
traveling wave velocity

$$v = \frac{1}{\sqrt{LC}}$$

Rearranging terms, the impedance exhibited by a wire can be expressed in terms of velocity and capacitance as:

$$Z_o = \frac{1}{vC}$$

Because the velocity of a traveling wave on a wire in air is almost equal to its free-space velocity (3×10^8 m/s) and the capacitance per meter of a 2-mm (0.08 inch) diameter wire is approximately 4.17 pF, then this same 2-mm diameter wire impedance is:

$$Z_o = \frac{1}{3 \times 10^8 \times 4.17 \times 10^{-12}} = 800 \text{ ohms}$$

The circuit can be considered to consist of two equal and opposite sign reactances (800 ohms) that correspond to two oppositely traveling waves, and a shunt

Maurice C. Hately, GM3HAT, 1 Kenfield Place, Aberdeen AB1 7UW, Scotland, UK.

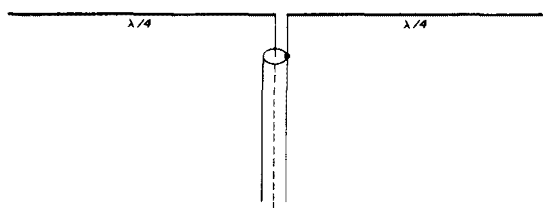


fig. 1. Traditional coax-fed half-wave dipoie.

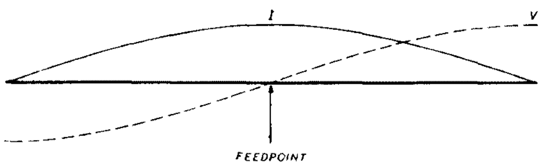


fig. 2. Symmetry of field conditions around basic dipole.

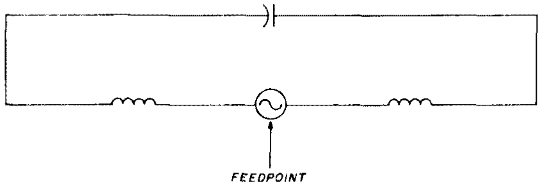


fig. 3. Equivalent resonant circuit of basic dipoie.

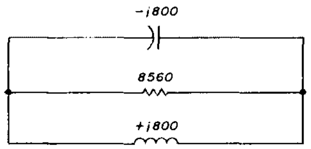


fig. 4. Parallel resonant circuit equivalent to practical dipoie.

resistance that represents total losses (mainly attributable, one would hope, to radiation into space). The half-power bandwidth of a half-wave dipole is 9.3 percent of the nominal resonance frequency.[5] *Q* is the reciprocal of the percentage bandwidth or equal to 1/0.093 = 10.7 (for a length-to-diameter (L/D) ratio of 10,000 and a height above ground of λ/4). The shunt loss resistance value (i.e., radiated power) in parallel resonance is reactance times *Q* or 800 x 10.7 = 8.56 k. On the other hand, the series equivalent "loss" resistance (series resonance) is 800/10.7, or approximately 73 ohms. **Figure 4** shows the complete parallel equivalent circuit. **Figure 5** shows the next progression, developed by splitting all three terms, which enables one to place at this location a virtual ground or balance point. Next, **fig. 6** shows the actual induction field couplings which exist from end to end. M shows the magnetic field and E shows the antiphase electric field coupling. (The electric field has two 180-degree out-of-phase components that are at the same time out of phase with the current maxima and magnetic field. In other words, the energy stored in the resonant system of the antenna has either most of its energy in the electric field, or a quarter of a cycle later in time, in the magnetic field.) These are not small effects — in fact. they are considerable and must therefore always be taken into account.

If Kraus had drawn the half-wave dipoie in this way, he would have shown it as it appears in **fig. 7**.[4] The extra -j42 ohms required for resonance, and the necessity for some balun in order to properly feed the coaxial cable, led me to decide to put in series two equal-value capacitors of -j21 ohms reactance and to feed the power across one of them as shown in **fig. 8**. The coaxial shield is now connected to the *electric field* center of the antenna. When first tried, this arrangement immediately showed promise in the removal of most of the local hash from machines, TV sets, and computers. But the VSWR on the feeder could not be reduced below 2:1 no matter what value capacitors were tried, or at which length or frequency the antenna was operated. Some of the problems must have been attributable to the unwarranted connection

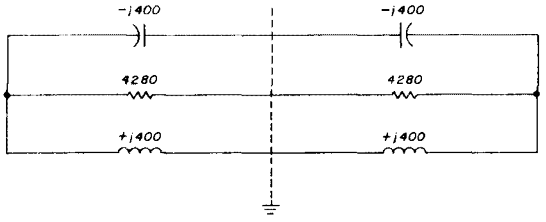


fig. 5. Equivalent circuit symmetrically splitting all three terms.

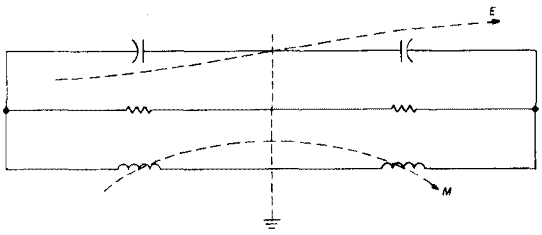


fig. 6. Equivalent circuit with accompanying symmetrical field.

of a capacitor of only 21 ohms across a 50-ohm feeder. It turns out that there are two solutions to this problem: you can install a series inductor before the capacitor (see **fig. 9**) or use a second resonant circuit, thereby making the antenna a dual-band radiator (see **fig. 10**). This approach extended its operating on two, three, four, or even five bands with low SWR, while still providing a balanced structure — hence the name, "Dipole of Delight," under which these capacitor dipoles are sold.

The additional reactance needed in the capacitive balun of the monoband dipole helped match the transmission line (50 ohms) to 800-ohm characteristic impedance of the antenna wires. It turns out that the optimum capacitive reactance is -j50 ohms (see **fig. 11**). If this is redrawn as a single-ended equivalent, all the components must be scaled down by a factor of $1/\sqrt{2}$ (This is due to the sharing of the load in the two halves and the doubling of the impedance on return to a dual, or balanced form (**fig. 12**). After slight rearrangement (**fig. 13**), the two capacitors are seen

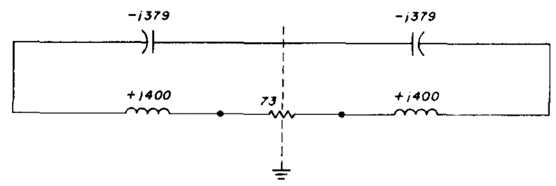


fig. 7. Symmetrical equivalent circuit with losses transformed to feed point.

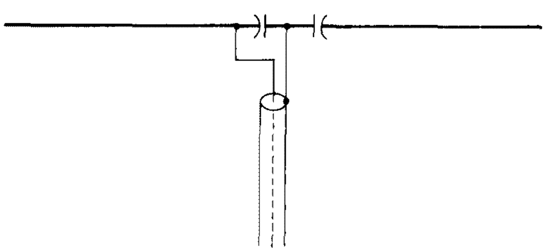


fig. 8. Basic capacitive balun system.

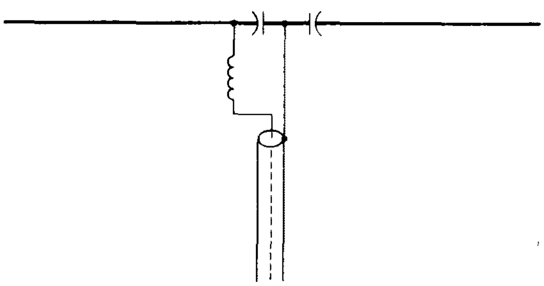


fig. 9. Additional inductor to correct feedpoint impedance; monoband antenna.

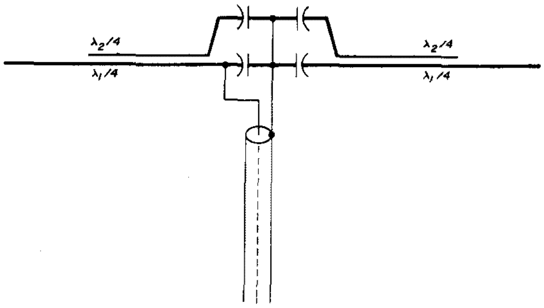


fig. 10. Alternative correction technique; multiband antenna.

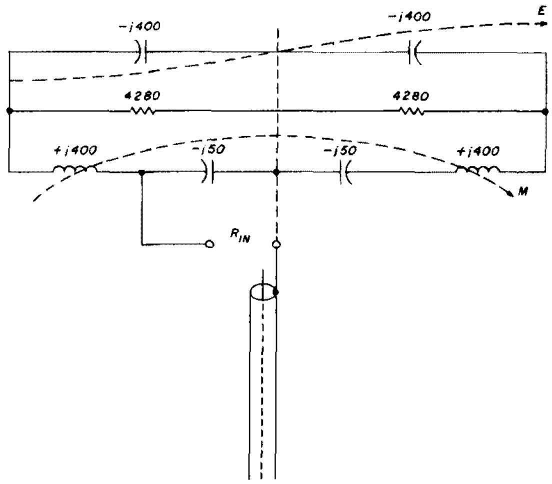


fig. 11. Optimum reactance values in parallel equivalent circuit of dipole.

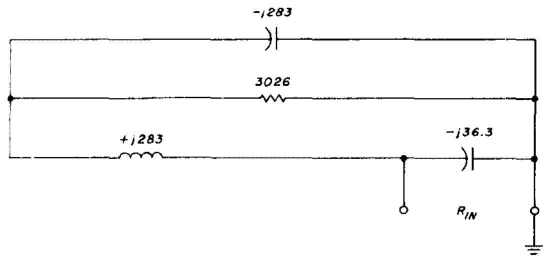


fig. 12. Rearrangement to show all losses transferred to one side of ground point.

as a capacitive autotransformer that works efficiently because of the considerable circulating current **I**. The equivalent inductive autotransformer is shown in **fig. 14**. The input resistance seen by the source is

$$3026 \times \left(\frac{36.3}{283}\right)^2 = 49.7 \text{ ohms}$$

Figure 15 shows a series inductive reactance of almost j50 ohms. This is needed to cancel out the equal

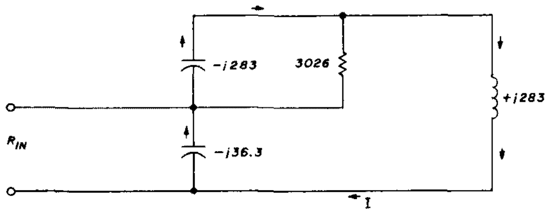


fig. 13. Circuit redrawn to show capacitive autotransformer.

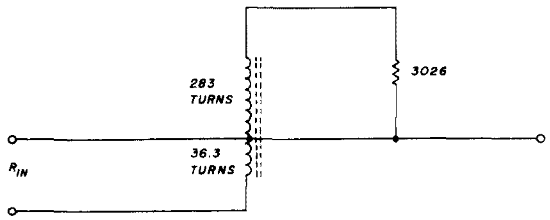


fig. 14. Analogous inductive autotransformer.

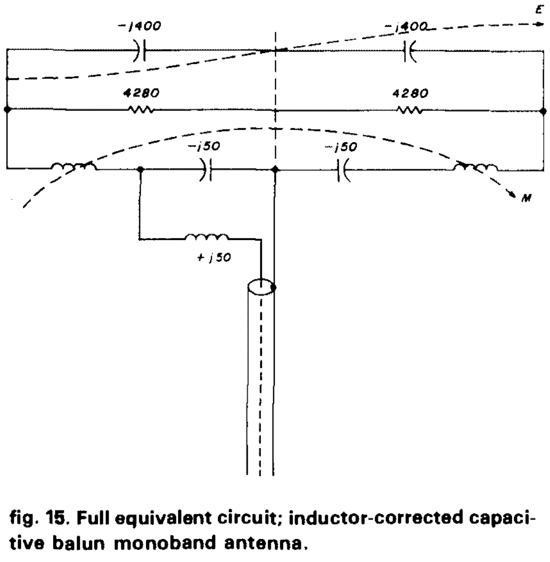


fig. 15. Full equivalent circuit; inductor-corrected capacitive balun monoband antenna.

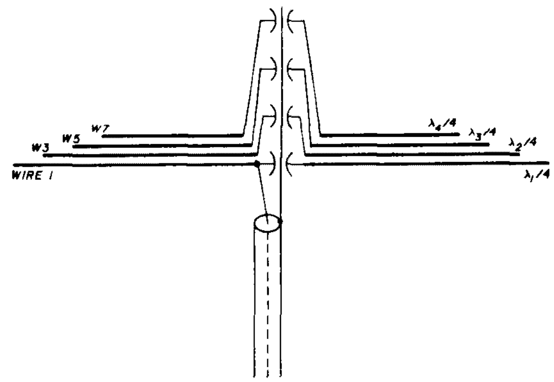


fig. 16. Four-band antenna.

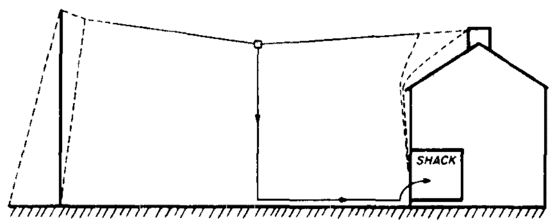


fig. 17. Preferred route of coax feeder.

Table 1. Input impedance is a genuine 50 ohms for a considerable bandwidth.

Frequency (MHz)	VSWR
13.7	1.45
13.8	1.25
13.9	1.14
14.0	1.08
14.1	1.03
14.2	1.02
14.3	1.07
14.4	1.13
14.5	1.22
14.6	1.30
14.7	1.40
14.8	1.50

and opposite capacitive reactance of 50 ohms, leaving a pure resistive termination of approximately 50 ohms. The *Q* of this resonant circuit is 1, and consequently does not affect the overall bandwidth of the system. The antenna bandwidth is determined by the *Q* of the dipole (10.7). As **table 1** shows, the input impedance is a genuine 50 ohms over a considerable bandwidth.

This second solution — i.e., the addition of a second, third, or fourth resonant system with voltage dividing capacitors, as shown in **figs. 10** and **16** — works by inducing current in the resistive components by inductive coupling from left-hand-traveling current in wire 1 to right-hand-traveling current in wire 2 into capacitor 2, and so on. **Table 2** gives the measured SWR values for a four-band antenna for the older hf Amateur bands. The system is not harmonic-dependent however, as can be seen in **table 3**, which lists data for a production version for the WARC Amateur bands.

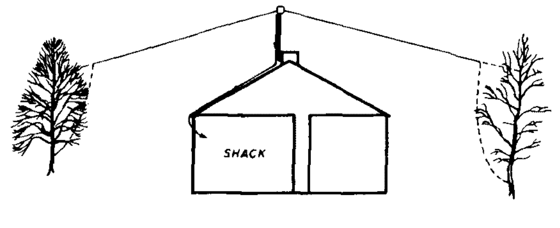


fig. 18. Route of chimney-supported inverted V.

Figure 19 shows the Smith chart display of the input impedance of a four-band Dipole of Delight when fed through approximately 50 feet of transmission line. The dot at the exact center of the chart represents exactly 50 ohms. Notice how closely the curve approaches this point for the 40, 20, 15, and 10-meter Amateur bands. **Figure 20** illustrates the effect with the feeder length canceled out. The equipment used for these experiments was a Hewlett-Packard Network Analyzer Model 8407A sweeping from 1 to 33 MHz.

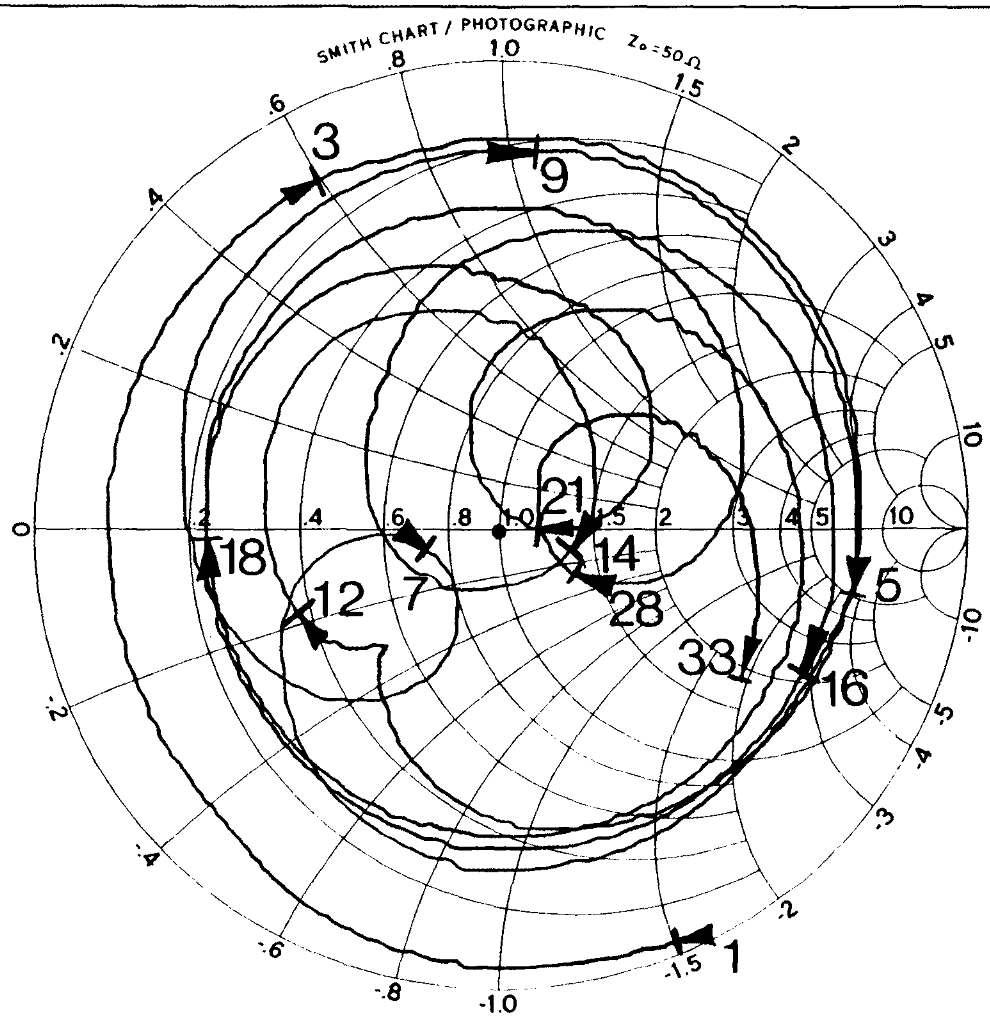


fig. 19. Input impedance of a four-band antenna at height of 8 meters (approx. 27 feet), fed by coax 15 meters (approx. 49 feet) long.

Table 2. Measured SWR values for a four-band antenna for the older hf Amateur bands.

Frequency (MHz)	VSWR
7.00	1.3
7.05	1.2
7.10	1.3
7.15	1.4
7.20	1.6
14.0	1.32
14.1	1.15
14.2	1.20
14.3	1.30
14.35	1.45
21.0	1.3
21.1	1.15
21.2	1.15
21.3	1.25
21.4	1.37
28.0	1.62
28.2	1.45
28.4	1.22
28.6	1.05
28.8	1.35
29.0	1.55

Table 3. Measured SWR values for a production version for the WARC Amateur bands.

Frequency (MHz)	VSWR
9.9	1.45
10.0	1.3
10.1	1.18
10.2	1.25
18.0	1.25
18.1	1.15
18.2	1.20
18.3	1.32
24.8	1.38
24.9	1.12
25.0	1.08
25.1	1.22

capacitor construction

The capacitors consist of etched double-sided epoxy-glass-fiber circuit board. One side is not etched at all and is connected to the coaxial cable shield. The other side is etched, leaving copper patches (in pairs) of sufficient size to provide the needed capacitance for each wire. The glass fiber acts as the dielectric of the capacitor. In this way a lightweight capacitor balun without too much wind-catching area and usable at a kilowatt PEP level can be made from single-layer pc board. The only reported failures have been thought to be due to lightning flashover across the unconnect-

ed right-side wires to the shield. A solution to this problem is presently being investigated. For medium powers — up to 100 watts of rf power output — lumped silver mica capacitors are used. These are easily concealed in a small center connector assembly which presents a negligible wind load. **Photo A** shows the center card and UHF connector and cable hanging from the water-shedding cowl.

ATU not needed

Since the VSWR is so close to 1:1 on 40 through 10, there's no need for an ATU between the transmitter and the antenna. This feature provides the freedom to QSY rapidly in a competitive situation without wasting time retuning. For blind or handicapped operators, it offers considerably simplified operation. For

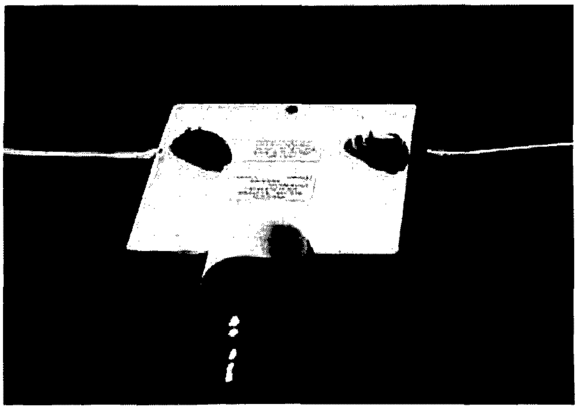


Photo A. Capacitor card of a three-band Dipole of Delight for 14, 21, and 26 MHz.

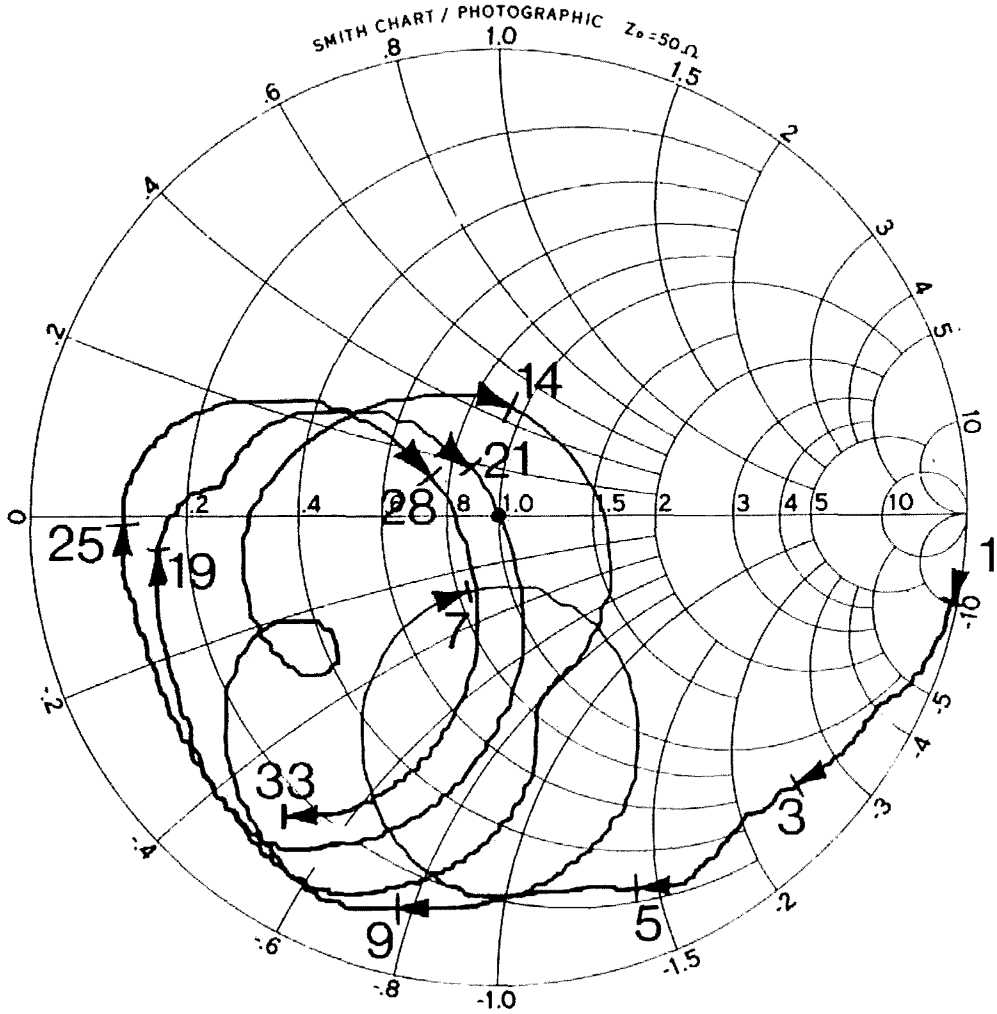


fig. 20. Antenna feedpoint input impedance as shown in fig. 19, but with effect of feeder cable counterbalanced out.

use with a no-tune semiconductor PA or linear, no antenna system could be more appropriate. The VFO is the only control that has to be moved!

Electrically, it's advantageous to have the shield of the coaxial cable at the rf zero potential right down to the shack. It should be emphasized that in order to preserve the balance, the cable should come away from the dipole at right angles until the feeder gets to an object such as the ground beneath the antenna, a tree, or a garage roof, for example, where it may then be turned to run to the shack along the same earth boundary (see **figs. 17** and **18**). This helps reduce VSWR. Observe SWR as shown in **fig. 17**, then pull the feedline to the side and watch the SWR rise from 1.02:1 and go up to 1.3:1. With the thorough balance of the Dipole of Delight it's never necessary to ground the case of the transceiver. There's a complete absence of rf feedback to the microphone and electronic keyer, and never any sign of "hand capacitance."

Because the feedline is at rf zero voltage right to the center balun unit, the Dipole of Delight works well as an inverted V. The support can be metal or any other material and there will be no effect on VSWR or radiation pattern.

helps TVI

Since no current flows down the outside of the feedline, no vertical polarization rf currents are induced into the downleads of nearby TV antennas. One disabled GM operator for whom ham radio is his main daytime activity (he tells me he is on 40 and 80 meters for 8 to 10 hours every day and likes to use his linear all the time) has found that a dual-band Dipole of Delight has not only cured TVI and BCI next door, but has also cured interference to an electronic organ at a church across the street. Now he can operate on Sunday mornings as well! We don't promise purchasers that TVI will be less than they've had with other antennas; in fact, the ground plane versions of these antennas[1,3] are definitely *not* recommended where TVI is a problem, though they are nevertheless useful for low-angle radiation, of course.

references

1. M. C. Hately, GM3HAT, "Multiband Dipole and Ground Plane Antennas," Patent Application No. 81 27439, September 10, 1981. (Granted UK Patent No. 2 112 579 and USA No. 4,518,968 from this priority date.)
2. M. C. Hately, GM3HAT, Lecture at Scottish Amateur Radio Convention, "Multiband Dipole and Ground Plane Antennas," Glenrothes, September 12, 1981.
3. M. C. Hately, "Multiband Dipole and Ground Plane Antennas," IEE Conference Proceedings No. 245, pages 102-106. (Lecture to IEE International Conference on HF Communications Systems and Techniques, February, 1985.)
4. J. D. Kraus, W8JK, *Antennas*, McGraw-Hill, 1948. (See Equation 10.59.)
5. L. A. Moxon, *HF Antennas for All Locations*, Radio Society of Great Britain, 1982, page 122.
6. National Research Development Corporation, British Technology Group, 101 Newington Causeway, London SE1 6BU.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

grounding, shielding, and isolating: part 2

Last month we discussed the problems of keeping outside interference from adversely affecting our equipment and preventing cross-interference between equipment in the same system.

Grounding problems affect not only single circuits, but collections of equipment as well. In fig. **1A**, we see a prescription for disaster: the equipment grounds are daisy-chained together and grounded to earth at a point close to only one piece of equipment, identified as *D*. Typically, the ground lines are small-diameter sections of wire not particularly appropriate for the purpose.

One way to correct this problem — the star ground — is illustrated in **fig. 1B**. Ground conductors from all four pieces of equipment are brought together at a common point, which is then grounded. Although it's difficult to achieve the exact configuration shown in fig. **1B** in an actual Amateur station, we can approximate it using the arrangement shown in fig. **2**. Keep in mind that our goal is to radiate as much of the available power as possible, while keeping spurious radiations (mostly harmonics) at home. Given the nature of most radio communications situations, if we have to sacrifice a little power at the fundamental operating frequency in order to lower the level of harmonics, then it's to our advantage to do so.

The signal flow logic for an hf station is shown in the inset in fig. **2**. The output circuit, a low-pass filter and an antenna matching network, surprises few Amateurs. The low-pass filter for hf usually has a cutoff frequency above the 10-meter band, but below 6 meters (36 and 42 MHz are often quoted in the advertisements). Above that frequency, attenuation is quite high.

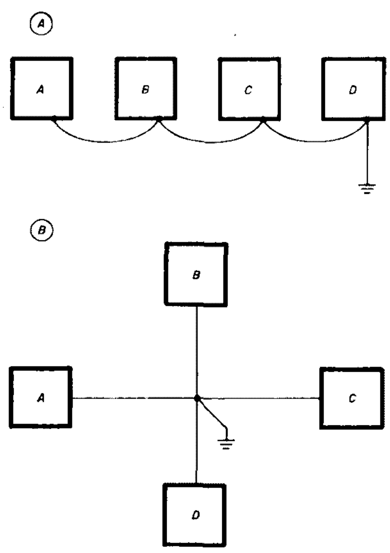


fig. 1. (A) Daisy-chain method of grounding equipment; (B) star grounding.

The antenna matcher is seen in many Amateur stations today because solid-state final amplifiers aren't tolerant of high VSWR loads. Such rigs include shut-down circuitry that reduces output power sharply when a VSWR greater than 1:1 is encountered. Previously, many Amateurs didn't use matching networks because tube-type finals used pi networks that could match a wide variety of antenna impedances. Many years ago, former ARRL President Vic Clark (W4KFC) told me that he recommended antenna matching networks even on well-matched antennas because they add another stage of relatively high-*Q* tuned circuitry between the transmitter and the antenna . . . and thus reduce TVI-producing harmonics.

What may come as a surprise to many readers is the low-pass filter at the input of the linear amplifier. Because the exciter/transmitter output signal isn't perfectly clean, and will contain harmonic energy, we should attenuate those signals prior to amplifying them in a 1500-watt amplifier! Use of a low-pass filter helps that situation tremendously.

There is one problem with using a low-pass filter on some solid-state equipment. Many linear amplifiers, especially grounded-grid designs, either don't have a 50-ohm input impedance or have a widely varying input impedance that is frequency dependent. The characteristics of LC low-pass filters are guaranteed only when the correct load impedance is presented to the filter (in our case normally 50 ohms, resistive). If the linear amplifier input impedance varies, then filter performance is adversely affected. In addition, the impedance reflected to the filter input will also vary. This

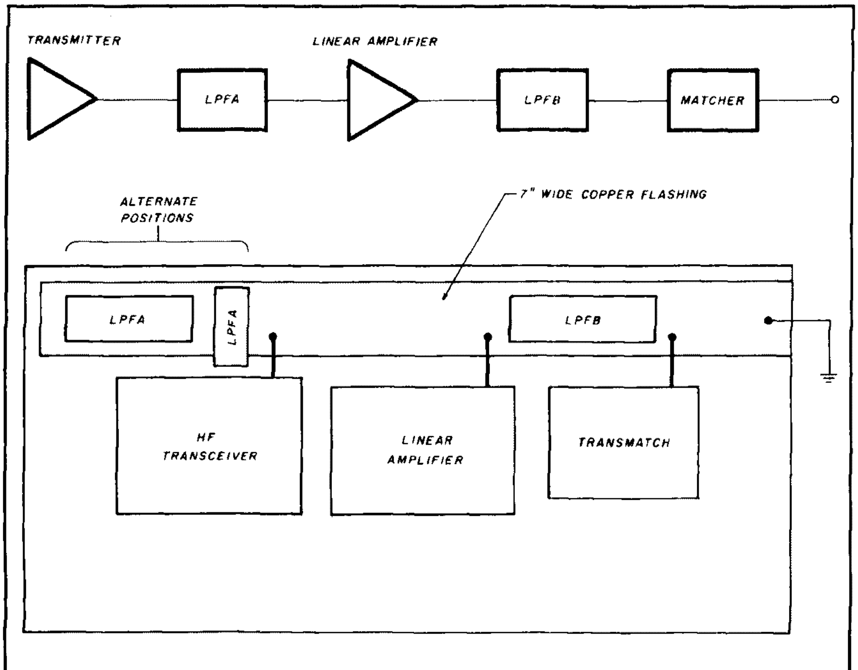


fig. 2. Grounding scheme at my previous QTH.

difficulty will cause a high VSWR to be seen at the transmitter output, causing it to fold back.

I experienced this problem using a Drake low-pass filter between a Kenwood TS-120 transmitter and a Heath SB-220 linear amplifier. There are two possible solutions. First, we can place a 50-ohm attenuator pad between the filter output and the linear amplifier input. The pad swamps out the impedance variations, although at the loss of some power. The attenuator pad method is recommended only where suitable resistors are available, and there's plenty of power to drive the linear and accommodate a 1- to 3-dB power loss. Second, we can either replace the low-pass filter with a variable matching network or add an antenna matcher to the circuit between the filter and amplifier. When I owned the TS-120, my solution was to use a Drake MN-4 matcher in place of LPF A (see **fig. 2**).

Note the configuration of the operating position in **fig. 2**. The equipment was mounted on a door converted into a table. The grounding system consisted of a piece of 7-inch wide copper roofing flashing along the back of the table. Though you probably won't find copper flashing at your local hardware store, it should be available from metal distributors and professional roofing supply outlets. (I found mine at a metal distributor after asking a neighbor, a contractor, where he bought his copper roofing supplies.)

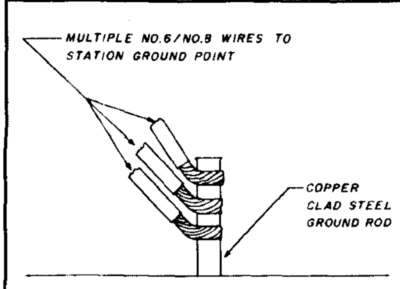


fig. 3. Multiple-wire grounding lowers inductance.

Although the cost per foot (or per pound, as some sell it) for the amount that you need will probably be relatively low, the distributor may want a $50 to $100 minimum purchase. Joining with other Amateurs in a group order, therefore, might be wise. Copper flashing, or similar copper stock, is sometimes available through artists' supply outlets in areas where copper bas relief engraving and smithing is popular. The stock he showed me was only about half as thick as roofing flashing, but should work just as well.

The copper flashing on my desk is grounded at one end with a ground rod. In the station where I used this system, the building was a well-constructed (i.e., heated and air-conditioned) shed in the backyard. I was able to drop the copper foil through a break between the wall and the floor, then sweat-solder it directly to a ground rod driven into the earth. In other cases, it's necessary to use a heavy ground wire between the desk and the ground rod.

ground wires

A ground wire must be short and nonresonant, and possess low inductance. As a result, it's usually best to use a piece of heavy flat braid rather than circular wire. You'll find braid for sale at some outlets, but it's often quite expensive. I've found it cheaper to strip the shield carefully from an appropriate length of RG-8 or RG-11 coaxial cable.

Low inductance is achieved by using a wide, short conductor. The braid mentioned above possesses this property. It's also possible to cut some of the copper flashing into slices thinner than 7 inches and use it for a ground conductor. In other cases, it's possible to approximate the ideal by using ordinary circular wire conductors, but be sure to use multiple lengths of conductor in parallel (**fig. 3**). Automotive parts stores are often the best sources for such wire stock. Use either No. 6 or No. 8 "primary wire" or copper battery cable wire.

The conductors can be either clamped to the ground pipe (or rod) or sweat-soldered. Because of the heat sinking capacity of the pipe and ground, it's usually necessary to use a torch for sweat-soldering. Either a propane torch, one of the home "brazing" torches sold in hardware stores, or a jeweler's torch will suffice for this

job. Choose your solder carefully, however. Some of the solder used for this purpose, and sold in local hardware stores, is acid-core. Also, some solders don't have the right metals mix. You want either resin core or coreless solder with resin flux, lead/tin solder of 50/50 or 60/40 mix.

Finally, make sure that the ground wire isn't resonant on either the fundamental frequency or one of the low order harmonics (e.g., second and third). Try to avoid even 1/8 or 1/4 wavelengths, even though this requirement may be difficult to achieve in practice on 80- to 10-meter antennas.

ground rods

The goal in a station ground system is to reduce the resistance between the radio and the earth. In most cases, this requirement translates to surface area in contact with the ground — and our job is to maximize that area. Several different options are available to us regarding ground rods.

First, we could do what a friend of mine did 20 years ago: he found an old copper bathtub in his grandfather's garage and buried it in an 8-foot deep hole. Considering the amount of work involved in burying a bathtub 8 feet underground, I'd prefer to sell the bathtub either for its metal content or its antique value . . . and use the proceeds to buy a truckload of proper ground rods!

Second, we could build a ground matrix grid on our property. When I was in high school, a local Amateur built a new home nearby. He arranged for several "custom extras" to the house. First, a concrete pedestal for the 60-foot tower was installed. Around the base of the tower was a series of eight or ten 8-foot copperclad steel ground rods. He then constructed a grid of No. 12 solid copper wire (bare) over the entire 150 x 175-foot lot. At each crossover point on the grid the conductors were soldered together. He also added several more ground rods at nodes around the lot. The grid was clamped and soldered to the tower grounding system, then attached to a rather massive 3-inch copper pipe coming through the wall of the house from the intended operating position. After this extensive ground system was installed, sod was brought in by the builder, who was clearly bewildered by the seemingly odd behavior of his eccentric client.

Third, we can use copperclad steel ground rod, available in several lengths from electrical supply outlets. Although this type is preferred for Amateur applications, surprisingly few Amateur outlets sell these rods in the proper lengths. The non-copperclad type, though less useful for Amateur applications, is also available.

Copperclad steel rods are normally sold in 4-, 6-, and 8-foot lengths. Ten-foot lengths, used by some power companies, are also occasionally available. Of these, the 8-foot length is probably the best, and may be the only one legal in your area. (Your local electrical inspector may have an enforceable opinion regarding your choice of ground rod. In many jurisdictions, electrical codes specify the 6- or 8-foot minimum length for towers and sometimes even Amateur stations.)

The 4-foot types, typically used by TV antenna installers, are the most common. But because they're less effective for both radio grounding and lightning protection, they should be avoided — except, perhaps, where multiple rods are used.

Another alternative is shown in **fig. 4**. This ground system, which uses a copper plumbing pipe, is especially useful for areas with hard clay-rich soil. The top end of the pipe is fitted with a "Tee" connector and short pipe sections to be used as a handle. One end of the handle is closed off with an end cap, while the other is fitted with a spigot nipple of the sort used to connect a garden hose. The bottom end of the 1-inch x 8-foot pipe is beveled to a point with a hacksaw. Drive the pointed end into the ground and apply water pressure. Although a bit messy, this method will allow you to work the pipe down into the soil with relative ease.

When you finish driving the copper pipe into the ground you will discover

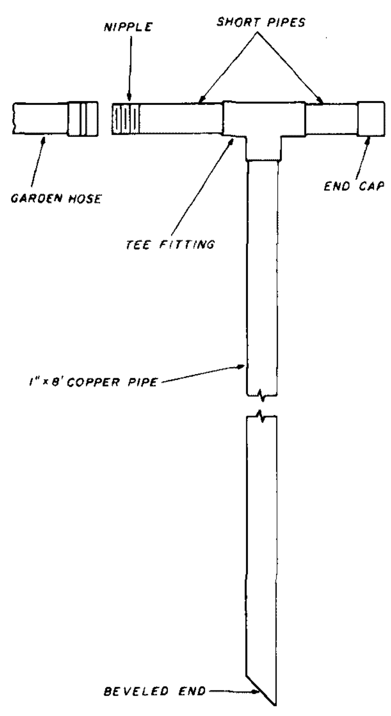


fig. 4. Pipe ground uses water pressure to simplify installation in hard soil.

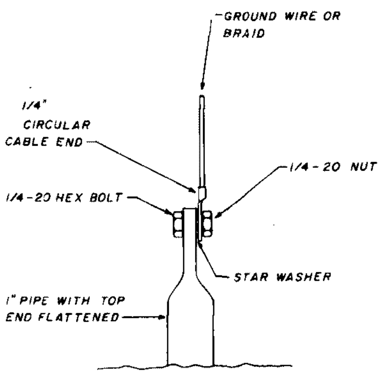


fig. 5. Adding connections to pipe ground.

one of the advantages of this system. With conventional ground rods you must either sweat-solder the ground wire (which is sometimes difficult), or use a clamp (which easily comes loose). The pipe end can be flattened with a heavy pair of pliers, hammer (with a 2 x 4 backstop used as an "anvil"), or other means. You can then drill one or more 1/4-inch holes in the flattened end to accept a nut and bolt to hold the ground wire (see **fig. 5**).

A word of caution is needed for those who are going to drive ground lines into the earth. Find out where the gas, water, sewer, and power lines are on your property. Although you can usually make intelligent guesses, some configurations are hard to determine. For example, at my old QTH, the gas line ran in a dog-leg path from the shutoff valve on the street to the meter on the back of the house. Unless you knew that the gas company was trying to serve two dwellings with the least amount of pipe, you wouldn't easily guess its path. Information on utility service run locations is often recorded on your survey plate, or in the local building inspector or engineer's office, or can be obtained from the utility involved. An 8-foot ground rod can disrupt these utilities — and that's always expensive and sometimes dangerous.

a warning on some defibrillator capacitors

In an earlier column I mentioned using medical defibrillator capacitors in high-power, high-voltage dc power supply filters. While that advice is still valid, a reader pointed out one possible pitfall. Some manufacturers of these machines depend upon the fact that defibrillator capacitors are charged for only a few minutes to de-rate some capacitors. As a result, in 7000-volt circuits they use capacitors with as little as 2000-WVDC dielectric strength. The small size of these capacitors enhances the portability of the product.

The capacitors to which I referred are high quality units manufactured by well-respected companies such as CDE and Sangamo; marked for 7500-WVDC or 10,000-WVDC, they're oil-filled and quite large. My reference capacitors came from American Optical and Hewlett-Packard (Model 7802) machines. No one has miniaturized those high-voltage capacitors significantly, so if a surplus defibrillator capacitor seems too small to be a 7 kV unit, then it probably isn't what it seems to be.

ham radio

gamma matching programs for the C-64/128

Simplify antenna matching with WB∅IKN's handy program

WB∅IKN's article, "Basic Gamma Matching"[1] provided a useful program for the Apple II+ computer. Because I needed gamma matching data for a homebrew project but have a C-64, I decided to convert the program. (If you own a Commodore 128, simply set the computer to 64 mode and you're ready to calculate.)

Figure 1 lists the revised program. The most significant modifications appear in the calculation lines. These changes were made to avoid exceeding the C-64's maximum input of 80 characters per statement.

I renumbered and compacted the program, adding an Option Menu from which you may choose to print hard copy, start new calculations, or end the program.

The final results were also truncated to two decimals; for practical purposes, this number of significant digits should be sufficient. The last three inputs of **line 10** change the screen/border/letter colors. If you prefer the standard blue, omit all POKE statements and colons in **line 10**.

design examples and program notes

To demonstrate the conversion program, and to allow you to check operation as well as the correctness of your data entry, I've used WB∅IKN's design examples. I suggest you read his article; for convenience — or in case you don't have a copy of the January, 1985, issue — I've summarized details below.

The hardest part will be determining the driven element impedance. Fortunately, the feedpoint characteristics of most common antennas are sufficiently documented to provide good data. Use your impedance meter or noise bridge, if no published data are available. You must know the diameter of your driven element and gamma rod. Then select an arbitrary gamma rod spacing. Use common sense, as in any homebrew project.

Load and run the program. Input the requested data when prompted. The computer will then calculate and display the results in the format shown in **figs. 3** and **4**.

If the values aren't acceptable, select Menu Option 2 ("all new calculations"). By trying a different gamma rod spacing or diameter, or varying the feedpoint impedance by slightly changing the length of the driven element, you can find the best combination with reasonable mechanical and electrical parameters. If the antenna isn't suitable for gamma rod matching, you'll learn this quickly, without tedious experimentation.

Figure 2 shows the screen display on a run for a computer-generated six-element, 20-meter Yagi design by Lawson.[2] The calculated feedpoint impedance of the antenna is 20 + j7.5 ohms. In this example, the assumptions are a 1.5-inch diameter element, a gamma rod diameter of 0.25 inch, and a gamma rod spacing of 3 inches.

additional designs

The results of two additional gamma match designs for the Yagi antenna are shown in **fig. 3**. In **fig. 3(A)** the gamma rod spacing has been increased to 6 inches; in **fig. 3(B)** the gamma rod diameter has been increased to 0.5 inch.

Figure 4 shows the results for a monopole approximately 1/4 wavelength high. In this case the

Fred A. Sontag, N∅CAO, Lake Farm, Route 1, Box 86, Tebbetts, Missouri 65080

```
10 PRINTCHR$(19)CHR$(147):POKE53280,9:POKE53281,0:POKE646,S
20 REM************************************
30 PRINT "GAMMA MATCH DESIGN"
40 PRINT "BY RICHARD A. NELSON - WB0IKN"
50 PRINT"FOR APPLE II+ COMPUTER"
60 REM*******************************************
70 PRINT:PRINT"ADAPTED & CUSTOMIZED FOR C64 WITH"
80 PRINT"OPTIONS FOR PRINT/NEW CALCS.& END"
90 PRINT"BY - FRED A.SONTAG,P.E. - N0CAO
100 REM*******************************************
110 PRINT"* VERSION 1.3 *":PRINT
120 DEF FN CSH(X)=LOG(X+SQR(X*X-1))
130 PRINT"ENTER <M> FOR MONOPOLE":OPEN1,0
140 PRINT"ENTER <D> FOR DIPOLE > ";:INPUT#1,DM$:PRINT
150 IF DM$="D" OR DM$="M" THEN GOTO170
160 GOTO130
170 PRINT "ENTER FREQ IN MHZ > ";:INPUT#1,F:PRINT
180 PRINT"ENTER FEEDPOINT RESISTANCE > ";:INPUT#1,RA:PRINT:IFDM$="D"THENRA=RA/2
190 PRINT"ENTER FEEDPOINT REACTANCE > ";:INPUT#1,XA:PRINT:IFDM$="D"THENXA=XA/2
200 PRINT "ENTER FEEDLINE RESISTANCE > ";:INPUT#1,RO:PRINT
210 PRINT:PRINT:PRINT"** THE FOLLOWING ARE IN INCHES **"
220 PRINT:PRINT"ENTER DRIVEN ELEMENT DIAMETER > ";:INPUT#1,K:PRINT
230 PRINT "ENTER GAMMA ROD DIAMETER > ";:INPUT#1,B:PRINT
240 PRINT "ENTER GAMMA ROD SPACING > ";:INPUT#1,S:PRINT:CLOSE1
250 H=(1+((FNCSH((4*S*S-K*K+B*B)/(4*S*B)))/(FNCSH((4*S*S+K*K-B*B)/(4*S*K)))))↑2
260 ZO=60*FN CSH((4*S*S-K*K-B*B)/(2*K*B)):T=H/ZO:A=((RO*XA)/(H*RA-RO))
270 W=(RO*((RA)↑2+(XA)↑2))/(H*RA-RO):Q=A+SQR(A*A+W)
280 XS=H*((RO*XA+SQR((RO*XA)↑2+RO*(H*RA-RO)*((RA)↑2+(XA)↑2)))/(H*RA-RO))
290 LDGA=ATN(Q*T):LDG=(LDGA*360)/(2*3.14159)
300 E=(RO/RA)*(((RA)↑2+(XA)↑2)/Q):G=(RO/RA)*XA
310 CR=1000000/(2*3.14159*(E+G)*F):PRINTCHR$(147)
320 IF DM$="D" THEN RA=RA*2:IF DM$="D" THENXA=XA*2:PRINT
330 IFDM$="D" THENPRINT"DIPOLE ANTENNA"
340 IFDM$="M" THENPRINT"MONOPOLE ANTENNA"
350 PRINT:PRINT"FREQUENCY <MHZ> = ";F
360 PRINT"DRIVEN ELEMENT DIAM = ";K:PRINT"GAMMA ROD DIAM = ";B
370 PRINT"GAMMA ROD SPACING = ";S:PRINT"DRIVEN ELEMENT RESISTANCE = ";RA
380 PRINT"DRIVEN ELEMENT REACTANCE = ";XA:PRINT"FEEDLINE RESISTANCE = ";RO
390 PRINT:N=LDG:GOSUB550
400 PRINT"GAMMA LENGTH <DEGREES> = ";U$:FT=(948/F)*(LDG/360):N=FT:GOSUB550
410 PRINT "GAMMA LENGTH <FEET> = ";U$:IN=FT*12:N=IN:GOSUB550
420 PRINT "GAMMA LENGTH <IN> = ";U$:CM=IN*2.54:N=CM:GOSUB550
430 PRINT"GAMMA LENGTH <CM> = ";U$:N=CR:GOSUB550
440 PRINT"GAMMA CAP IN PF = ";U$
450 PRINT:PRINTTAB(13)CHR$(18)"OPTION MENU"CHR$(146):PRINT
460 PRINT"1. HARDCOPY"
470 PRINT"2. ALL NEW CALCULATIONS"
480 PRINT"3. END"
490 OPEN1,0:PRINT"PRESS OPTION NO.- THEN PRESS RETURN ";:INPUT#1,X:PRINT
500 IFX=1THENCLOSE1,0:GOTO530
510 IFX=2THENCLOSE1,0:GOTO10
520 IFX=3THENCLOSE1,0:PRINTCHR$(147):END
530 OPEN3,3:OPEN4,4:PRINTCHR$(19);:FORI=0TO679:GOTO540
540 GET#3,A$:PRINT#4,A$;:NEXT:CLOSE3:CLOSE4:PRINTCHR$(147):GOTO470
550 U$=STR$(N):L=LEN(U$):PD=0:FOR I = 1 TO L:IF MID$(U$,I,1)="."THEN PD=I
560 NEXT I:IF L <= (PD+2)THENRETURN
570 R$=MID$(U$,(PD+3),1):U$=LEFT$(U$,(PD+2)):IF R$<"5"THENRETURN
580 U=ABS(VAL(U$))+.01:U$=STR$(U*SGN(N)):RETURN

READY.
```

fig. 1. Gamma matching program listing for the C-64/128.

```
GAMMA MATCH DESIGN
BY RICHARD A. NELSON - WB0IKN
FOR APPLE II+ COMPUTER

ADAPTED & CUSTOMIZED FOR C64 WITH
OPTIONS FOR PRINT/NEW CALCS.& END
BY - FRED A.SONTAG,P.E. - N0CAO
* VERSION 1.3 *

ENTER <M> FOR MONOPOLE
ENTER <D> FOR DIPOLE > D
ENTER FREQ IN MHZ > 14.200
ENTER FEEDPOINT RESISTANCE > 20.0
ENTER FEEDPOINT REACTANCE > +7.5
ENTER FEEDLINE RESISTANCE > 50


** THE FOLLOWING ARE IN INCHES **

ENTER DRIVEN ELEMENT DIAMETER > 1.5
ENTER GAMMA ROD DIAMETER > .25
ENTER GAMMA ROD SPACING > 3.0



DIPOLE ANTENNA

FREQUENCY <MHZ> =  14.2
DRIVEN ELEMENT DIAM =  1.5
GAMMA ROD DIAM =  .25
GAMMA ROD SPACING =  3
DRIVEN ELEMENT RESISTANCE =  20
DRIVEN ELEMENT REACTANCE =  7.5
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  28.8
GAMMA LENGTH <FEET> =  5.34
GAMMA LENGTH <IN> =  64.09
GAMMA LENGTH <CM> =  162.78
GAMMA CAP IN PF =  188.92

OPTION MENU

1. HARDCOPY
2. ALL NEW CALCULATIONS
3. END
PRESS OPTION NO.- THEN PRESS RETURN
```

fig. 2. Screen display for a sample run showing the sequence of data entry and output. (See text for 20-meter Yagi description.)

gamma rod is a length of No. 10 wire (approximate diameter = 0.1 inch). **Figure 4(A)** is for a 60-foot tower used as a vertical radiator on 3.8 MHz. (WB0IKN's computer analysis shows its impedance to be approximately 33 + j1.3 ohms. **Figure 4(B)** is for a 55-foot tower operated on the same frequency. The results show how a smaller gamma capacitor may be used if the radiator is made capacitively reactive by reducing its overall height.

```
DIPOLE ANTENNA

FREQUENCY <MHZ> =  14.2
DRIVEN ELEMENT DIAM =  1.5
GAMMA ROD DIAM =  .25
GAMMA ROD SPACING =  6
DRIVEN ELEMENT RESISTANCE =  20
DRIVEN ELEMENT REACTANCE =  7.5
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  25.32
GAMMA LENGTH <FEET> =  4.7
GAMMA LENGTH <IN> =  56.34
GAMMA LENGTH <CM> =  143.12
GAMMA CAP IN PF =  241.89
```

fig. 3A. Calculated results for additional run on the antenna described in fig. 2, showing gamma rod spacing increased to 6 inches.

```
DIPOLE ANTENNA

FREQUENCY <MHZ> =  14.2
DRIVEN ELEMENT DIAM =  1.5
GAMMA ROD DIAM =  .5
GAMMA ROD SPACING =  3
DRIVEN ELEMENT RESISTANCE =  20
DRIVEN ELEMENT REACTANCE =  7.5
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  38.34
GAMMA LENGTH <FEET> =  7.11
GAMMA LENGTH <IN> =  85.32
GAMMA LENGTH <CM> =  216.72
GAMMA CAP IN PF =  262.10
```

fig. 3B. Calculated results for additional run on the antenna described in fig. 2, showing gamma rod diameter increased to 0.5 inch.

```
MONOPOLE ANTENNA

FREQUENCY <MHZ> =  3.8
DRIVEN ELEMENT DIAM =  12
GAMMA ROD DIAM =  .1
GAMMA ROD SPACING =  12
DRIVEN ELEMENT RESISTANCE =  33
DRIVEN ELEMENT REACTANCE =  1.3
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  44.82
GAMMA LENGTH <FEET> =  31.06
GAMMA LENGTH <IN> =  372.69
GAMMA LENGTH <CM> =  946.64
GAMMA CAP IN PF =  122.62
```

fig. 4A. Results of run for a 75-meter vertical monopole antenna on 3.8 MHz, (60-foot tower).

```
MONOPOLE ANTENNA

FREQUENCY <MHZ> =  3.8
DRIVEN ELEMENT DIAM =  12
GAMMA ROD DIAM =  .1
GAMMA ROD SPACING =  12
DRIVEN ELEMENT RESISTANCE =  25
DRIVEN ELEMENT REACTANCE = -38
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  53.73
GAMMA LENGTH <FEET> =  37.24
GAMMA LENGTH <IN> =  446.82
GAMMA LENGTH <CM> =  1134.92
GAMMA CAP IN PF =  76.99
```

fig. 4B. Results of run for 75-meter vertical on 3.8 MHz, (55-foot tower).

As stated previously, I strongly recommend that you read WB0IKN's article and also the publications dealing with gamma matching design and construction referenced therein.

references

1. Richard A. Nelson, WB0IKN, "Basic Gamma Matching," *ham radio*, January, 1985, page 29.
2. James L. Lawson, W2PV, "Yagi Antenna Design", *ham radio*, July, 1980, page 19.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

optimized 2- and 6-meter yagis

Several years ago I decided to take a different approach to 2-meter EME. The idea was to build an array of eight small Yagis mounted on a short tower. The stacking frame would be attached to a single boom not exceeding 30 feet. Such a system could be mounted conveniently in my back yard with minimum interference to existing structures and would be easily transportable for EME DXpeditions.

It seemed reasonable that a physically small Yagi with a clean radiation pattern and high gain-per-unit boomlength could be designed.[1] Small Yagis require only short, low-loss phasing lines. If this approach was successful on 2 meters, I concluded, the design could later be scaled to 70 cm (432 MHz), where the individual Yagis could be rear-mounted and possibly rotated in polarity for EME operation.[2]

I decided that a 12-foot boom, 144-MHz Yagi might be the ideal answer for the individual antenna; 12-foot boom material is readily available, and short Yagis can be mounted on towers that are only 12 to 15 feet high.

Several designs emerged for both 2 and 6 meters. While some of the results of this study were unexpected, they do answer several frequently asked questions.

where to begin

I started by designing a 2-meter Yagi on a 12-foot boom. Obviously, the boomlength could not exceed 142 inches — which, at 144 MHz, is approximately 1.75 wavelengths. I wanted the sidelobes to be as low as possible, at least 16 to 18 dB in the E plane, and a minimum of 13 dB in the H plane. If improved performance was possible, so much the better.

I studied but quickly discarded the NBS Yagis because the only designs near my requirements, 1.2 or 2.2 wavelengths, were either too short or too long.[3] Then I considered the Greenblum designs.[4] Unfortunately, design information was incomplete; furthermore, previous Yagi designs using the Greenblum tables didn't produce very clean radiation patterns, especially in the H or vertical plane.

Several articles in the *IEEE Proceedings* discussed a method of optimizing Yagi performance through the use of nonequally spaced and nonuniform length elements.[5,6] They started with an initial six-element design using equal spacing and director lengths. The elements were 0.0067 wavelengths in diameter on a 1.49 wavelength boom. The reflector was 0.51 wavelengths long and spaced 0.25 wavelength behind the driven. All directors were equally spaced at 0.31 wavelength and were 0.43 wavelengths long.

They ran a program similar to that used by Morris[7] — the forerunner of the one used by W2PV[8] — on a large IBM computer. It calculated the gain of this antenna at 11.2 dBi, with relatively high first sidelobes.

Maintaining the same reflector length and spacing, believed to be near optimum, the director spacings were mathematically iterated (adjusted in small steps) for maximum gain. This step increased the Yagi gain by 1.65 dB to 12.85 dBi. However, the boomlength had increased to 1.70 wavelengths, and all director spacings were now unequal. The pattern was definitely cleaner, but not terrific. The next step involved adjusting the reflector length and spacing, but very little improvement resulted.

A further improvement in the computer program through the use of larger matrices allowed for the simultaneous iteration of element spacing *and* length. The results were quite gratifying. After several optimizations, a new Yagi design with approximately the same boomlength (1.69 wavelengths with a gain of over 13.4 dBi) emerged, showing *an improvement of 2.2 dB* over the original constant length and spacing design and a cleaner radiation pattern.

Some preliminary conclusions can be drawn as a result of this study. With a fixed number of elements, there is a particular boomlength for optimum gain. Furthermore, gain and pattern aren't optimum when constant director length and spacing are used. For best Yagi performance, the boomlength and all element spacings and lengths must be individually optimized.

implementing the design

Limited practical information was, however, available for the "optimized" Yagi design. No element diameter scaling information was available to me at that time (in the mid-1970s) and the diameters recommended were rather impractical — over 0.5 inch at 2 meters! Therefore I decided to scale my own design by overlaying the element lengths on an NBS-type of scaling graph.[3] I designed a 144-MHz Yagi using 3/16-inch diameter rod (0.0023 wavelength diameter at 144 MHz).

I built this antenna and tested it on a commercial antenna range. The gain was as predicted. However, the bandwidth for maximum gain was very nar-

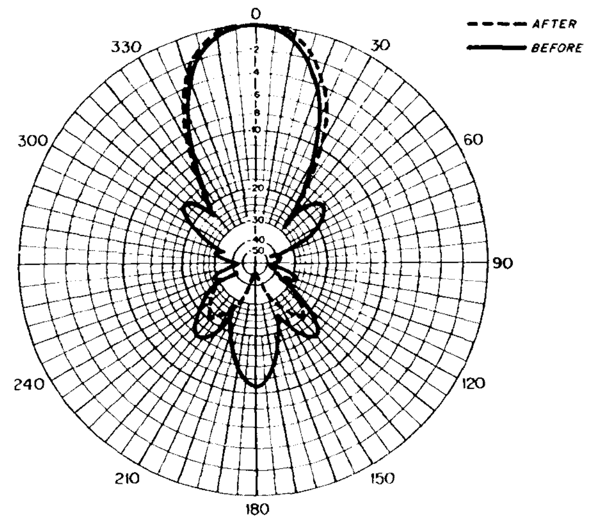


fig. 1. E plane radiation pattern of the original (solid lines) and modified (dotted lines) Yagi. Modifications involved lengthening the reflector and significantly shortening the last director.

row, only about 1.0 MHz at the −1 dB points, and gain peaked near 146 MHz. Back to the drawing board!

Based on the data taken on the antenna range, I was able to correct my scaling graph. I then scaled the design to 50.1 MHz. It worked like a champ. The lengths and spacings chosen are shown in the first and second columns of **table 1**. A typical antenna radiation pattern is shown in **fig. 1**.

Upon close inspection of the radiation pattern, however, the f/b ratio wasn't worth writing home about. Dave Olean, K1WHS, figured that he could trade gain, if necessary, for a better f/b ratio. He left the element spacings constant, but shortened the last director by almost 10 inches; by lengthening the reflector a few inches, he was able to obtain a nearly infinite f/b ratio, though over only a very narrow bandwidth. The cost was about 1 dB in forward gain. The pattern of the modified Yagi is superimposed on the original design in **fig. 1**. The final element lengths chosen are shown in column 3 of **table 1**.

A close inspection of the patterns illustrated in **fig. 1** shows that the sidelobes aren't as good as my original design goals. Also, the improved f/b design had lower gain than desired. With the help of John Kenny, W1RR, a computer optimization was conducted on a similar six-element Yagi design scaled to 2 meters.* The results were similar to those reported in references 5 and 6. Either maximum gain or reasonable f/b ratio *could* be achieved, *but not simultaneously!*

I decided to make another search and again reviewed the Greenblum designs.[4] Using his designs, I found that eight elements were required for a 1.75-wavelength boom. I quickly calculated a 144-MHz design and W1RR computed the radiation pattern with his program. The gain was right on the money, but as previously speculated, the radiation pattern had very high sidelobes.

Next John ran an optimization routine on my new eight-element design. The input design parameters were maximum gain with all side and rear lobes at least 18 to 20 dB down *in the* E plane, with the overall boomlength fixed at 1.734 wavelengths (142 inches at 144 MHz).

After many computer iterations, a new design emerged. The pattern looked too good to be true. The gain penalty for a clean radiation pattern was only a few tenths of a dB, not a big compromise for over 13 dBi gain! The bandwidth of the design was also very good — several MHz at the −1 dB points.

I hurriedly ran out and built the optimized design using leftover materials from Cushcraft 2-meter beams. Cushcraft uses above-the-boom element mounting, which requires a 0.312-inch element extension when mounted on a 1.0-inch diameter boom. A T match with a 4:1 half-wave balun completed the design. Construction details on the final design are shown in **fig. 2**.

Soon afterwards, the improved design was measured on a commercial antenna test range and was found to be satisfactory. A typical radiation pattern is shown in **fig. 3**. All side and rear lobes were about 20 dB down, and the gain was only 0.75 dB less than the NBS 2.2-wavelength design that used a trigonal reflector. Not bad for a design with a lot less hardware, six fewer elements and a 36-inch shorter boom!

Seven more copies were built along with the necessary phasing lines. They were assembled into a "quick and dirty" 2-meter EME array consisting of a 30-foot irrigation tube for the main boom, four 12-foot vertical masts, and a 12-foot portable tower. The spacing was 8-1/2 feet horizontally and 8 feet vertically. The VSWR of the entire array was fine. A photo of the completed array is shown in **fig. 4**.

The rest is history. On October 17, 1981 — even before making a single QSO — we broke it down and immediately set off for Rhode Island, where we fired it up for the first time on EME. In two nights of activity, we worked 25 stations in 16 states off the moon. Several stations completed a 2-meter WAS; only two stations scheduled were missed, but they turned out to be no-shows. Not bad performance for a small transportable array with only 64 elements!

*Yagi analysis programs for computing gain and patterns of specific Yagi designs are readily available.[8-11] However, the programs used to *optimize* Yagi designs are much more complex and not available for distribution. They're experimental, use proprietary software, and usually require a large mainframe computer. Therefore, I'd urge you *not* to contact persons doing such work until their programs are suitable for distribution.

insulated element mounting

Since the original Yagi was constructed, insulated through-the-boom element mounting has become quite popular.[9] Fortunately, the same dimensions as those shown in **fig. 2** can be used, since the correction factor for through-the-boom with insulated elements is about the same as the one used in the original design. Just maintain a 1.0-inch diameter boom and 3/16-inch element diameters with insulators and keepers as described in reference 9. However, the driven element length and/or the lengths and spacings of the T match will probably have to be optimized if low (1.2:1 maximum) VSWR is to be maintained.

I've used the eight-Yagi, 2-meter array on EME for several years. WAC was accomplished with less than 600 watts of output in the shack. Several European stations are using this Yagi on tropo and meteor scatter. Several local Amateurs and I have also used it to put rare grids on the air, since it's so compact and uncluttered.

This Yagi design is highly recommended where a small, simple, high-gain antenna with excellent sidelobe suppression is preferred. It's easily duplicated and can be used singly or as part of an array. Despite its size, four of these Yagis stacked 8-1/2 feet horizontally and 8 feet vertically make a good beginner's 2-meter EME array. Eight are better for the more serious EMEer, yet still affordable.

A secondary benefit of this 2-meter array hasn't previously been discussed, *but may be worth mentioning.* Because of space limitations, I can't fit both a 2-meter and a 135-cm (220 MHz) EME array in my back yard at the same time. But fortunately, if you use the 4.2-wavelength NBS Yagi designs on 135 cm, the mechanical spacings used on 2 meters just happen to be the same as the optimum mechanical spacing for 135 cm.[3] In my case, when I change bands I just swap out the Yagis, reconnect the same phasing lines, change the power dividers, and presto! For just an hour or so of changeover effort, I'm on 135-cm EME. (A photo of this array on a 1984 expedition to New Hampshire, using the same tower and stacking frame, is shown in reference 10).

6-meter Yagi

Shortly after this 2-meter Yagi design was completed, several Amateurs who needed a high-performance, high-

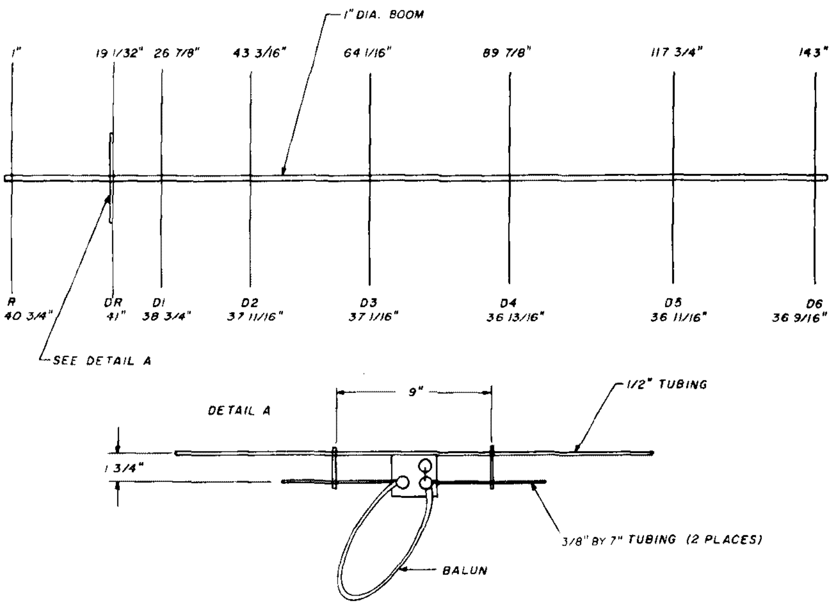


fig. 2. Optimized eight-element, 2-meter Yagi construction details. The reflector and directors are 3/16-inch rod. Element location is referenced from rear of boom to avoid tolerance buildup. A 4:1 half-wave type balun made from RG11 75-ohm coax is used. Overall length of the balun including connectors is 25 inches.

Table 1. Length and spacing for six-element, 6-meter Yagi.

Element	Spacing (inches)	Element length (inches)*	Element length (inches)**
R		113.75	117.0
	59.0		
DR		113.0	113.0
	68.0		
D1		104.75	104.75
	95.5		
D2		103.88	103.88
	75.5		
D3		104.25	104.25
	100.0		
D4		103.88	93.88

*Maximum gain model.

Optimized for best f/b ratio. A 2-inch diameter, 33-1/2 foot boom is used. The elements are 3/4-inch diameter, and are attached to the boom with U-bolt mounting as shown in **fig. 5C. A 0.625-inch element lengthening correction is included for this method of boom mounting.

gain 6-meter Yagi with clean radiation patterns — one that would also be usable on EME — approached me. Their requirements seemed to call for a frequency-scaled copy of the 2-meter design. At 6 meters, this would require a boomlength of about 35 feet.

Several mechanical configurations were evaluated. It appeared that a boom diameter of at least 2 inches was in order. "Through-the-boom" element mounting (**fig. 5A**), either directly in contact with or insulated from the boom, was immediately discarded since it would severely degrade the mechanical strength of the boom. Insulated elements mounted above the boom are advisable, but require special materials (**see fig. 5B**).

Several commercial element mounting methods were also evaluated. Cushcraft uses large diameter (3/4 inch) elements on its 6-meter "Boomer"™ and places a U-bolt directly through the element with a stiffening half-diameter element above and below the element (**fig. 5C**). Wilson antennas (now out of production) used a different mounting method that doesn't pierce the element (**fig. 5D**). Finally, with the help of Don Cook, K1DPP, a homebrew nonpiercing above-the-boom mounting was also fabricated (**fig. 5E**.)

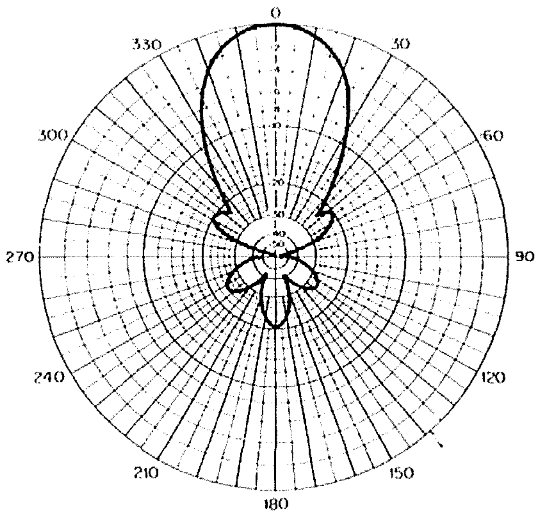


fig. 3. E plane radiation pattern of the optimized 8-element Yagi. Both the 2- and 6-meter models have the same radiation pattern.

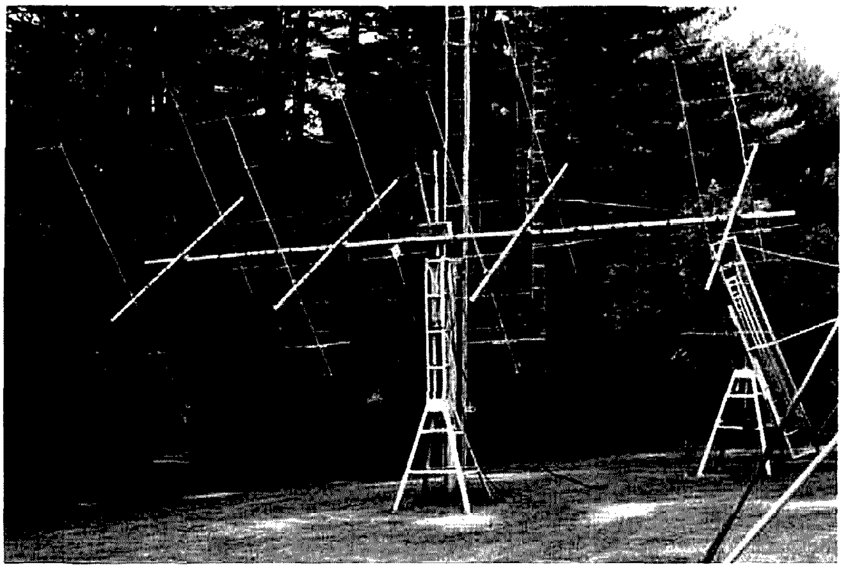


fig. 4. 2-meter EME array uses eight of the optimized Yagis.

The final element mounting scheme chosen was that shown in **fig. 5D**, since many of the older Wilson eight-element antennas are still available and easily modified for the new design. However, any of the above-the-boom mounting schemes shown will work satisfactorily. If you don't have an old Wilson beam to modify, I recommend the element mounting scheme shown in **fig. 5E**. More on this shortly.

Based on the use of an obsolete Wilson eight-element Yagi, the 2-meter design was scaled to 50.1 MHz. This design uses a 4-foot section of 5/8-inch diameter tubing for the inner portion of the elements and 1/2-inch diameter tubing for the outer portion of the elements. Construction details are shown in **fig. 6**.

Several 6-meter Amateurs have used this design. Each has used a slightly different set of tubing for the driven element matching, so the sizes shown for the driven element matching assembly may need some final adjustment. Either the length of the driven element and/or the length and spacing of the matching section may have to be changed slightly to suit your individual design.

If you build your own from scratch, the element mounting schemes shown in **figs. 5C, D** or **E** are recommended. The elements used may be either 1/2-, 5/8-, or 3/4-inch diameter tubing, or you *can use graduated* tubing as shown in **fig. 6**, since the difference in tuning is negligible (less than 100 kHz). If you use insulated mounted elements as shown in **fig. 5B**, *each of* the elements should be shortened approximately by 5/8 inch.

If you're building from scratch, I

recommend the use of a 30-foot length of irrigation pipe measuring 2 inches in diameter. This is available in farming supply stores. To obtain the required 35-1/2 foot length, a 1-7/8 inch outside diameter tube can be telescoped into the end of the tubing near the last director. Suitable tubing can be obtained from WD4BUM.**

Any boom this length and size should be supported from above. Two suggested methods are shown in **fig. 7**. This beam is large and has a high wind load, so any short cuts can turn into an expensive disaster.

If you decide to build your own, use the element mounting method shown in **fig. 5E**. A 2-inch wide aluminum channel measuring 1/2 inch thick and 5 to 6 inches long is recommended. It's easy to file out a semicircular groove in the channel to match the boom curvature. *Don't file too deeply; the strength of the channel will be diminished if you go all the way down to the base plate.*

The elements are held to the channel with short pieces of aluminum straps approximately 1/2 inch wide, 1/16 inch thick, and 2-1/2 inches long. These straps are held in place with stainless steel screws, nuts, and washers. For best element alignment, each channel should be attached to the boom using two U-bolts. Suitable stainless steel U-bolts can be purchased from suppliers such as WB9IPG*** or homebrewed.

At the suggestion of K1DPP, I made my own U-bolts using 3/16-inch diameter stainless steel welding rods available from a local welding supply house. All that was required was a 10-32 die, a die handle, and some patience. If you'd like to try this, First de-burr the edges of the rod and then cut the required length of threads on both ends. Next, place a 2-inch diameter tube upright in a bench vise. Place about a 6-inch piece of suitable diameter tubing over each threaded end of the rod. Then carefully bend the rod around the 2-inch diameter tube until the desired U-shape is obtained.

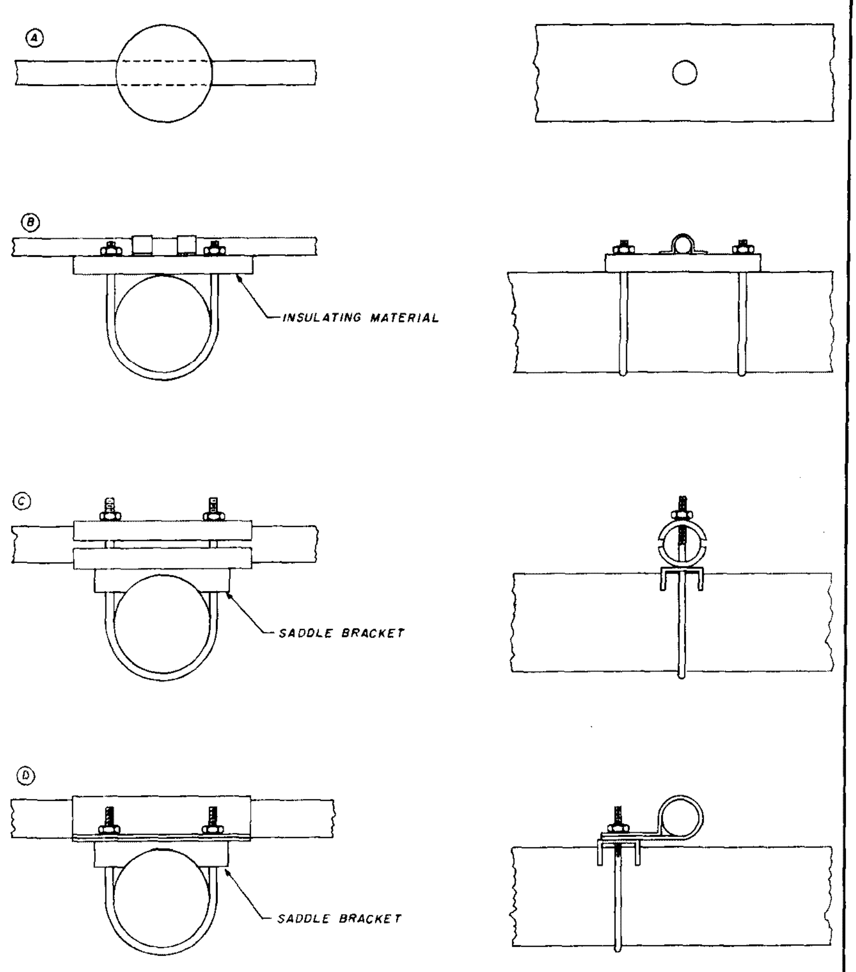


fig. 5. Typical element mounting methods: (A) through-the-boom insulated, or in direct contact with the boom; (B) insulated above the boom; (C) element held in contact with the boom by a U bolt; (D) element held by special bracket. (Because of last-minute production problems, fig. 5E will appear next month. — Ed.)

6-meter results

The performance of the 6-meter Yagi design has been gratifying to all who built one. Some Amateurs used it in contests to set high scores. Compared with most other designs, the pattern is very clean, and the gain definitely matches or exceeds that of any other 6-meter Yagi designs, even those with more elements or longer boomlengths.

Ray, WA4NJP, who's been active on 6 meters for many years and has used several different Yagi designs, recently built a large array for 6-meter EME. After finding his results only marginal, he asked for my recommendation.

I gave him the details shown in **fig. 6**, and he built four of the 6-meter Yagis, stacking them 28-1/2 feet in the E plane and 24 feet in the H plane. He started hearing EME echoes on 50 MHz immediately. Recent tests have yielded EME echoes regardless of where the moon is in the sky; previously, he could use the moon only when it was at low elevations to obtain horizon gain. Echoes more than 10 dB above the noise are now quite common off the moon — even on SSB!

**George Shira, WD4BUM, Route 7, Box 258, Anderson, South Carolina 29624.

***H. C. Van Valzah Company (WB9IPG), 1140 Hickory Trail, Downers Grove, Illinois 60515.

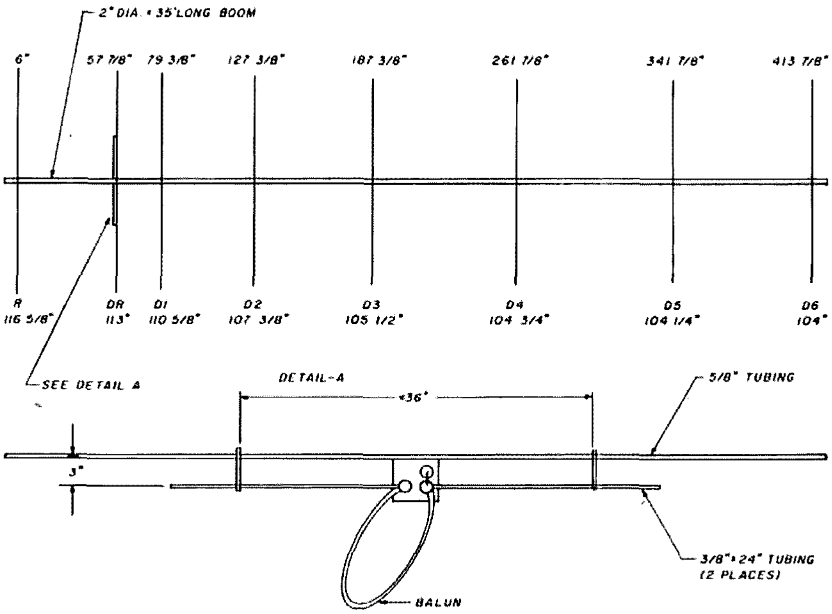


fig. 6. Optimized eight-element, 6-meter Yagi construction details. Element location referenced from rear of boom to prevent tolerance buildup. A 4:1 half-wave type balun made from RG11 75-ohm coax is used. Overall length of the balun including connectors is 78 inches. Coax can be coiled up in a 6- to 9-inch diameter and taped to boom.

summary

Since these Yagis were originally designed, additional data has indicated that optimum boomlengths exist for Yagi antennas, especially those shorter than 4 wavelengths.[1] The optimum boomlength for short Yagi designs seems to be an odd multiple of quarter-wavelengths (i.e., 0.25, 0.75, 1.25, and 1.75 wavelengths). If these boomlengths are used with the proper number of elements, optimum gain and pattern can often occur simultaneously. According to my analysis, the optimum number of elements for any specific boomlength seems to follow those recommended by Greenblum.[4] Furthermore, the use of a T match with a built-in 4:1 half-wave type balun, as shown in **figs. 2** and 6, is strongly suggested.

This month's column was primarily aimed at the design of shorter boomlength Yagis. Emphasis was on performance, with high gain-per-unit boomlengths and clean radiation patterns. Several designs for 2 and 6 meters that meet the criteria specified above were discussed. These designs should be just the ticket for those who want high performance with an antenna they can modify or build for themselves.

acknowledgements

Any project this size requires plenty of help. I'd especially like to thank John Kenny, W1RR, for his work on optimizing the designs. Thanks also to Dave Olean, K1WHS, for his assistance with measurements and the optimization of the f/b ratio on the six-element 6-meter design. Stan Jaffin, WB3BGU, has been particularly helpful in analyzing my results and comparing notes on this and other designs. Thanks also go to Don Cook, K1DPP, for his help with the 6-meter antenna mounting brackets and hardware. Finally, thanks to Ray Rector, WA4NJP, for trusting my designs enough to build his large 6-meter EME array that works so well. I hope I didn't forget anyonel

new records

In last month's column I predicted

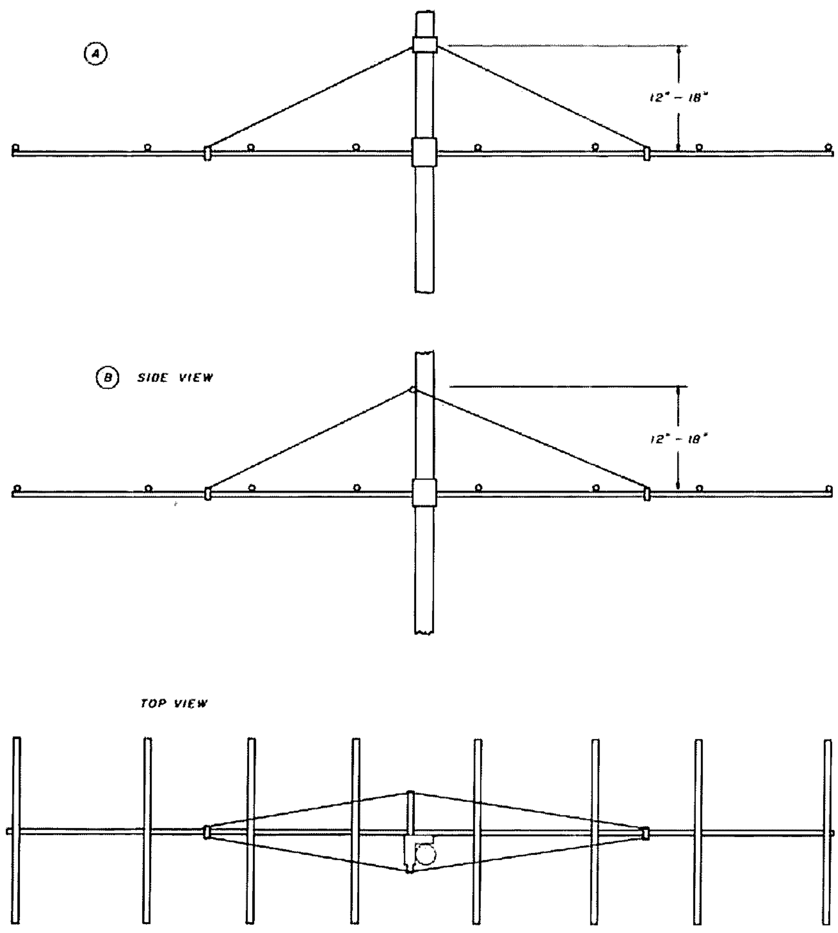


fig. 7. Recommended boom mounting method for extra strength: (A) use 1/2-inch or larger diameter tubing approximately 10 feet long mounted about 18 inches above the boom at the center. Flatten tubing ends and attach to mast and boom with U bolts. (B) Use Phillystran™ or equivalent cable mounted as shown to prevent swaying (side and top views).

that before the April issue was printed, the 33-cm (903 MHz) record would again be broken.[12] On Christmas Eve, 1986, another unexpected Midwest tropo opening occurred; this time, Sam, W2PGC (FN02OR), completed a two-way QSO with Gary, K3SIW/9 (EN52WA), for a record-shattering distance of 478 miles (769 km). Both stations were using modest setups, 10 and 70 watts, respectively, and single-loop Yagi antennas. Signals were S9 each way, and the contact was completed on two-way SSB. Congratulations to Sam and Gary.

East Coast VHF Society

One of the first of its kind, the East Coast VHF Society is now being reactivated by president Russ Pillsbury, K2TXB, vice-president Roger Amidon, K2SMN, secretary Allen Katz, K2UYH, and treasurer Tom Kirk, KA2VAD. There are plans for a newsletter and an annual flea market, as well as antenna and noise figure measuring contests in July. Equipment loan and activity to various rare grids are also planned. Contact K2UYH for further information.

MININEC 3 is available

From time to time I've mentioned computer-aided antenna modeling programs. Till now, these computer programs were either difficult to obtain, not generally available, or suitable only for mainframe or other large computers.

All that has changed. MININEC 3 is now available for general distribution for use on IBM and IBM-compatible personal computer systems. This program is faster than its predecessor and has more available options. To obtain your copy, send an MS DOS-formatted, double-sided, double-density disk with sufficient return postage and a note requesting a copy of MININEC 3 to Jim Logan, Code 822, Naval Ocean Systems Center, 271 Catalina Boulevard, San Diego, California 95152-5000.

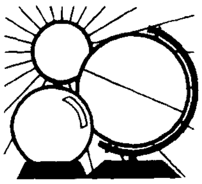
important VHF/UHF events

May 2-3	West Coast VHF Conference (contact WB6GFJ)
May 5	Predicted peak of the Eta Aquarids meteor shower at 1300 UTC
May 8	ARRL 902-MHz Spring Sprint Contest (Friday evening)
May 9	2304 EME special by WA2WEB (contact K2UYH for skeds)
May 14	ARRL 1296-MHz Spring Sprint Contest (Thursday evening)
May 15	EME perigee
May 15-17	13th Annual Eastern VHF/UHF Conference, Nashua, New Hampshire (contact W1EJ)
May 23-24	ARRL 50-MHz Spring Sprint Contest (Saturday evening)
June 7	Predicted peak of the daytime Arietids meteor shower at 1900 UTC
June 10	Predicted peak of the Zeta Perseids meteor shower at 0400 UTC
June 13	EME perigee
June 13-15	ARRL June VHF QSO Party
June 20-21	SMIRK 6-Meter QSO Party Contest (contact KA0NNO)
June 21	±1 month. Peak of Sporadic E propagation

references

1. Joe Reisert, W1JR, "VHF/UHF World: Yagi Facts and Fallacies," *ham radio*, May, 1986, page 103.
2. Joseph H. Reisert, Jr., W6FZJ/1, "VHF Antenna Arrays for High Performance," *QST*, December, 1974, page 38.
3. Joseph H. Reisert, Jr., W1JR, "How to Design Yagi Antennas," *ham radio*, August, 1977, page 22.
4. Carl Greenblum, "Notes on the Development of Yagi Arrays," *QST*, August, 1956, page 11.
5. David K. Cheng and C. A. Chen, "Optimum Element Spacings for Yagi-Uda Arrays," *IEEE Transactions on Antennas and Propagation*, September, 1973, page 615.
6. C. A. Chen and David K. Cheng, "Optimum Element Lengths for Yagi-Uda Arrays," *IEEE Transactions on Antennas and Propagation*, January, 1975, page 6.
7. *I. Larry Morris, "Optimization of the Yagi Array, 1," PhD Thesis, Harvard University, October, 1964.*
8. *James L. Lawson, W2PV, "Yagi Antenna Design: Performance Calculations,"* ham radio, January, 1980, page 22.
9. Joe Reisert, W1JR, "VHF/UHF World: A High-Gain 70-CM Yagi," *ham radio*, December, 1986, page 75.
10. Joe Reisert, W1JR, "VHF/UHF World: 220-MHz EME Requirements," *ham radio*, September, 1984, page 45.
11. Stanley Jaffin, WB3BGU, "Applied Yagi Antenna Design," Part 6, *ham radio*, October, 1984, page 89.
12. Joe Reisert, W1JR, "VHF/UHF World: 33-CM Update," *ham radio*, April, 1987 page 00.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

1986 propagation review

Now that most of the geophysical and propagation data for 1986 is in and has been analyzed, let's review the significant events so you can compare them with your DX operating log.

There were only four major geomagnetic-ionospheric disturbances (i.e., those with a geomagnetic A index greater than 40) during the year and eight large ones (i.e., those with an A index greater than 30). Surprisingly, April was the quietest month. The four major disturbances occurred in February, May, September, and November; with the exception of the September disturbance, these occurred as the 27-day solar flux cycle was decreasing. The February event (from February 5 to February 10) was so extraordinary that it warranted special coverage in the July, 1986, column.

The next major solar event, which occurred from May 1 through May 4, included a geomagnetic-ionospheric disturbance (to K7) at 1200 UT on May 2. On May 3, an old-cycle solar flare at 2017 UT (with signal attenuation in the United States and in the Pacific area) produced protons at the polar regions at 1255 UT on the following day, with the next geomagnetic-ionospheric disturbance (to K6) about 2100 UT on May 5. A decrease of as much as 22 percent in mid-latitude maximum usable frequencies (MUF) occurred on east-west paths, which included QSB.

On September 11 at 1837 UTC, the next major event occurred during a period of relatively constant solar flux. Possibly attributable to a small new-cycle flare, it produced a sudden-commencement geomagnetic-ionospheric disturbance. As a result of a favorable sun-earth equatorial alignment, an A of 49 and a K of 7 were registered, with an aurora visible as far south as Albuquerque, New Mexico, and Columbia, Missouri. MUFs decreased 25 percent on September 12, with considerable fading and weak signals occurring on east-west paths. There must have been good transequatorial openings to southern areas on this one, but I didn't hear of them.

The last of the four events took place in early November, as the solar flux decreased from its October 23 peak. The driving forces for this event were probably several small old-cycle flares and numerous solar flux bursts, the largest of which occurred on October 31 at 2249 UT. A sudden-commencement geomagnetic-ionospheric disturbance (to K6) started on the November 3 at 2354 UT and ended at 1500 UT on the 5th. A decrease of 20 percent in the MUF during the early part of the 4th was experienced on east-west paths to Europe from this short disturbance. This MUF decrease is related to equatorward extension of the lower F layer electron density of the auroral Atlantic trough situated between 60 to 70 degrees north latitude. Signal levels on the normal great circle paths are lower and QSB is experienced. However, perhaps other less common paths were useful and resulted in some interesting DX in your log.

new forecasting tool —via computer BBS

In October 1978 the Institute for Telecommunication Science of the Department of Commerce in Boulder, Colorado, stopped providing radio propagation quality information to the public via mailed weekly bulletins and WWV broadcasts of "N7's" at 14 minutes after the hour. These were replaced with solar flux and geomagnetic A and K data included with the geophysical alert announcements at 18 minutes after the hour. With the help of articles by Ted Cohen, N3AT, George Jacobs, W3ASK, and others of us, hams became their own forecasters.

Now the Space Environment Services Center (SESC) in Boulder has resumed radio quality reporting with an expanded, worldwide version of the "N7" report/forecast system. They've divided the northern hemisphere into a grid of four longitude quadrants, 0 to 90 and 180 degrees east and west, and five latitude zones, 0-10-30-55-70-90 degrees north. A two-digit code (such as N7) appears in each grid space. The letter (W, U, or N) represents conditions for the current 6-hour period; the number (1 through 9) indicates the forecast for the next 6-hour period. The primary forecast is at 0600 UT daily with 6-hour updates.

You can use your computer terminal to obtain these forecasts from SESC's "bulletin board" service. Call (303) 497-5000 with the usual 300/1200-baud, 8-bit (1 stop bit, no priority) conventional protocol of bulletin board systems. An simple menu will allow copying data for up to 5 minutes. Registration (entering your name and intended use) will give you a user number and extend available data-copying time to 15 minutes. User acceptance of the experimental service will assure permanence and menu expansion.

last-minute forecast

The higher frequency bands, 10 through 30 meters, are expected to be favorable for DX openings the first and last weeks of the month, when the possibility of higher solar flux is greatest. Short-skip sporadic-E openings are also possible during the last week or so. On the lower bands, the middle weeks should be best, with higher daytime and nighttime signal strengths. Atmospheric noise (thunderstorms) may be building up generally now, but not significantly — so enjoy these bands while you can.

Of interest to moonbounce DXers, the lunar perigee occurs on the 15th with a full moon occurring on the 13th. The Aquarid meteor shower, of interest to meteor-burst DXers, peaks be-

MAY

WESTERN USA

GMT	PDT	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	5:00	20	30	20	12	15	12	10	15
0100	6:00	15	*30*	*20*	12	15	10	10	15
0200	7:00	15	*30*	*20*	15	20	10	10	15
0300	8:00	15	*30*	*20*	15	20	10	10	15
0400	9:00	20*	30	*30*	20	20	10	10	15
0500	10:00	20	20	*20*	20	30	12	10	15
0600	11:00	20	20	15	20	30	12	12	20
0700	12:00	20	*20*	15	20	30	15	15	20
0800	1:00	20	*30*	20	*20*	30	15	20*	20
0900	2:00	*20*	*30*	20	*20*	30	20*	20	20
1000	3:00	*30*	20	20	*30*	30	20	20	20
1100	4:00	*20*	20	20	*20*	30	20	20	*30*
1200	5:00	20	20	15	20	*40*	*20*	20	*30*
1300	6:00	20	20	12	20	*40*	*20*	20	*30*
1400	7:00	20	15	12	15	*40*	*20*	*20*	20
1500	8:00	20	15	10	12	*40*	*20*	*30*	*30*
1600	9:00	20	15	10	12	*40*	*20*	*30*	*30*
1700	10:00	20	15	10	12	20	20	*30*	*30*
1800	11:00	*20*	15	12	12	20	15	*30*	20
1900	12:00	*30*	15	12	12	20	12	20	20
2000	1:00	*20*	20	15	12	15	12	15	20
2100	2:00	20	20	15	10	15	12	12	20
2200	3:00	20	20	20	10	15	12	12	20
2300	4:00	20	20	20	10	15	12	10	15

MID USA

GMT	MDT	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)	CDT
0000	6:00	20	20	20	12	15	10	10	15	7:00
0100	7:00	20	*30*	*20*	12	15	10	10	15	8:00
0200	8:00	20	*30*	*20*	15	20	10	10	15	9:00
0300	9:00	15	*30*	*20*	15	20	12	10	20	10:00
0400	10:00	20*	20	*30*	20	20	12	12	20	11:00
0500	11:00	20	20	*20*	20	30	12	12	20	12:00
0600	12:00	20	*30*	20	20	30	15	15	20	1:00
0700	1:00	*30*	*30*	20	*20*	30	15	15	20	2:00
0800	2:00	*20*	*30*	20	*20*	30	20	20	*30*	3:00
0900	3:00	*20*	20	20	*30*	40	20	20	*30*	4:00
1000	4:00	20	20	20	*20*	40	20	20	*30*	5:00
1100	5:00	20	20	15	20	*40*	20	20	20	6:00
1200	6:00	20	20	12	20	*40*	20	20	20	7:00
1300	7:00	20	20	12	15	*40*	*20*	20	20	8:00
1400	8:00	20	15	12	12	*40*	*20*	*30*	*30*	9:00
1500	9:00	20	15	10	12	*40*	*20*	*30*	*30*	10:00
1600	10:00	20	15	10	12	*40*	*20*	*30*	*30*	11:00
1700	11:00	20	15	10	12	20	*20*	*30*	*30*	12:00
1800	12:00	*30*	15	12	12	20	12	*30*	20	1:00
1900	1:00	*30*	20	12	10	20	12	20	20	2:00
2000	2:00	*20*	20	15	10	20	12	15	20	3:00
2100	3:00	20	20	15	10	15	12	12	20	4:00
2200	4:00	20	20	20	10	15	12	12	15	5:00
2300	5:00	20	20	20	12	15	10	10	15	6:00

EASTERN USA

GMT	EDT	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	8:00	20	20	20	12	20	10	10	15
0100	9:00	20	20	*20*	12	20	10	10	15
0200	10:00	20	30	*20*	15	20	12	10	20
0300	11:00	20	*30*	*20*	20	30	12	12	20
0400	12:00	*20*	*30*	*30*	20	30	15	12	20
0500	1:00	*20*	*30*	*20*	20	30	15	15	20
0600	2:00	*20*	*30*	20	20	30	15	15	20
0700	3:00	*20*	*30*	20	*20*	30	20*	20	*20*
0800	4:00	20	20	20	*20*	40	20	20	*20*
0900	5:00	20	20	20	*30*	40	20	20	20
1000	6:00	20	20	15	*20*	40	20	20	20
1100	7:00	20*	20	12	20	*40*	20	20	20
1200	8:00	15	20	12	15	*40*	20	20	20
1300	9:00	15	20	12	15	*40*	*20*	20	20
1400	10:00	20*	20*	10	15	*40*	*20*	*30*	*20*
1500	11:00	20	15	10	12	*40*	*20*	*30*	*30*
1600	12:00	20	15	10	12	*40*	*20*	*30*	*30*
1700	1:00	20	15	10	12	20	20	*30*	*30*
1800	2:00	20	15	12	10	20	15	*30*	20
1900	3:00	*30*	20*	12	10	20	15	15	20
2000	4:00	*30*	20	15	10	20	15	15	20
2100	5:00	*30*	20	15	10	20	12	12	20
2200	6:00	20	20	20	12	20	12	12	15
2300	7:00	20	20	20	12	20	10	10	15

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

tween May 4 and 6, with rates of 10 to 25 per hour for the northern and southern hemispheres, respectively.

band-by-band summary

Ten, twelve, fifteen, and twenty meters will support DX propagation from most areas of the world during daylight and into the evening, with long-skip out to 2000 miles (3500 km) per hop. Signals on the upper three bands arrive mainly from the southern countries and occur near noontime. Sporadic-E short-skip will be available on some days toward the end of the month near local noon. The direction of propagation will follow the sun across the sky: morning to the east, south at midday, and west in the evening.

Thirty, forty, eighty, and one-sixty meters are the nighttime DXers' bands. Because of low solar flux in midmonth, daytime DX — particularly in the early mornings — *may* be worthwhile. The direction of propagation follows the darkness path across the sky: evening to the east, south and north around midnight, and toward the west in the predawn hours. Distances will decrease to 1000 miles (1600 km) generally, for skip on these bands. Sporadic-E openings will be observed most frequently around sunrise and sunset toward the end of the month.

ham radio

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

HOT/NEW PACKET PROGRAMS FOR YOUR IBM PC. Several telecommunications programs to choose from, especially written to interface your packet controller with your PC or compatible/clone. Features like Full Screen, Line Screen editing, Split Screens, ASCII, Binary, X-Modem or user defined file transfers, DOS shell, Macro Keys, Command Files, many types of time/date/oper. ID. Multi-page brochures explain them all. Software Support. Write for new information and pricing. KALT & ASSOCIATES, 2440 E. Tudor Rd, Suite 138, Anchorage, AK 99507. (907) 248-0133. Charge Cards accepted.

HOMEBREW PROJECTS LIST SASE. WB2EUF, Box 708, East Hampton, NY 11937.

FOR SALE: Tower, Rotator, Antenna Package—Tri-Ex W-67 Tower, motorized extension from 22' (nested) to 67' plus mast height. Hand winch operated tilt-over feature. CDE Ham III Rotator. Wilson DB-33 (10/15 meter beam). Cushcraft 20 meter beam. Very good condition. Package price $1250 firm. WA1USO, Fred Moller, Old Fitzwilliam Rd, Jaffrey, NH 03452. (603) 532-7635.

PERFORATED ENCLOSURES 17 x 8.5 x 7.5 deep with grey paint and 17 x 8.5 x 11 deep with iridite finish. Unpainted blank front panel. Approximately 50 each. $10 and $15 respectively. Quantity discount available. Don Reed, K0IFO, 911 North Lynn, Independence, MO 64050. (816) 252-9436.

DISCOVER "THE RADIO WORKS". See what we are doing with high performance HF and VHF antennas, parts, and accessories. Unusual 48 page discount catalog. 22 cents SASE. The RADIO WORKS, HRAPR, Box 6159, Portsmouth, VA 23703 (804) 484-0140.

R-390A RECEIVER: $195 check; $115 reparable. Parts, tubes, sections. Info SASE. Mint military-spec pull-out 12AT7, 6AG5: $15/dozen. CPRC-26 six meter transceiver (see Ham Radio, March 1985) $17.50 apiece, $32.50 pair (add $4.50/unit shipping). Baytronics, Box 591, Sandusky, OH 44870. (419) 627-0460 evenings.

VHS VIDEO CASSETTES $29.50 total price for a box of 10 delivered anywhere in continental U.S. Call for 24-hour order information. KB6MT (714) 990-9622.

WANTED TO BUY zip code and directory published before 1980 publication No. 65. Bernard Fair, 19455 Houghton, Detroit, MI 48219.

S.S.B. CRYSTAL FILTERS. 9.0 MHz, 2.2 kHz bandwidth, six pole, with data $20.00 postpaid. OEM quantity available. ICL7117 D.V.M. I.C.'s direct drive 3-1/2 digit LED same as 7107 plus hold, with data; $6.00. 2/$10.00 postpaid. Dentron Scout C.A.P. transceiver, 4 MHz, 100 watts, new; $250.00. A.C.P.S. $75.00 postpaid. George Misic, 14481 Watt, Novelty, Ohio 44072.

DC to 400 MHz Spectrum Analyzer Kit. For info SASE to: A & A ENGINEERING, 2521 W. La Palma Ave. #K, Anaheim, CA 92801. (714) 952-2114.

MOTOROLA C-34MSY MOTRAN 402-420 UHF Base Stations. Sold by individual strips only: RX, TX, TCN-10-58A control chassis w/squelch gate and station logic cards, and TLN-8204A meter panels. No channel elements. $25.00 ea strip including postage, add $3.00 for Air Parcel Post. Also 2 C-34RCB MICOR base stations—make offer. Greg Westrup, WA9BWZ, 202 C Avenue, Apt D, Kodiak, AK 99615. (907) 487-2476.

FOR SALE: TR-7950, 25 watt 2 meter transceiver with mobile mount. $275.00 FOB. (401) 789-1817. W1CPI.

LEARN MORSE CODE IN 1 HOUR. Amazing new easy technique. Moneyback guarantee. $10. Bahr, 2549H Temple, Palmbay, FL 32905.

SUPERFAST MORSE CODE SUPEREASY. Subliminal cassette. Moneyback guarantee. $10. Bahr, 2549H Temple, Palmbay, FL 32905.

ANALOG AND RF CONSULTING for the San Francisco Bay area. James Long, Ph.D N6YB (408) 733-8329.

TEN-TEC now shipping new-boxed USA made latest 1987 factory models Corsair II, Century 22, Argosy II transceivers. Titan linear amplifier 229A 2kw antenna tuner plus accessories, antenna. For the best Ten-Tec deal write or phone Bill Slep (704) 524-7519, SLEP ELECTRONICS COMPANY, Highway 441, Otto, NC 28763.

WANTED Schematic for Bearcat 100 Electra, Model BC-100 Scanner. Please contact Ralph E. Smith, 857 Rougemont, St. Foy, Quebec City, Canada.

HEATH Deluxe antenna tuner Model SA2060—a beauty—best offer. (401) 789-1817 FOB.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

COLLINS KWM-380. Fully updated. Excellent condition. Full service manual. Write or call. W3IRE, 9436 Howes Road, Dunkirk, MD 20754. (301) 257-3041.

BACK ISSUES OF HAM RADIO Magazine from March 1968 to June 1974. Complete your collection. Individual issues $4.00 each. KX9P (319) 377-3563.

IBM/APPLE COMPUTER program "Hamlog". 18 modules logs auto-sorts 7-band WAS/DXCC. Full feature. Also CP/M. Apple $19.95, IBM $24.95. HR-KA1AWH, PB 2015, Peabody, MA 01960.

BOUND VOLUMES CQ 1958/69, 73 1963/72, Audio 1957/68, Radio Electronics 1950/69, Radio News (Electronics World) 1950/69, Electronics 1953/73, $5 per year plus shipping. Also some later individual issues. K4QOK, 307 Old Fort, Tullahoma, TN 37388.

IBM-PC SOFTWARE: CW Keyer. COM sends CW from RS232 port, any speed, using type ahead buffer, memory or disk. $29.50. ELEC. EXE solves most common electronic equations, $19.50. Bill Feldmann, 6677 Charing St, Simi, Calif. 93063, or SASE for details.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521-5280.

WANTED: EIMAC 8873 tube for Heath SB-230. Please contact G2DRT, F.S.G. Rose, 84 Cock Lane, High Wycombe, Bucks HP 13 7 EA England.

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252.

NJ-NJ-NJ-NJ-NJ-NJ-NJ-NJ A Full-Service Ham-SWL-CB-Scanner store in NJ. Discount Grand Opening Prices. Top performing radio systems for every budget. New 10 meter and VHF/UHF rigs. ARRL, Amphenol, Astatic, Astron, Azden, B&W, Bilal Belden 9913, Butternut, Clear Channel, KLM, Larsen, MFJ, Mirage, Mil Spec Cables, much more. Open M-F 10 AM-9PM. Sat 10 AM-7 PM. Buy and sell used gear and have qualified repair facility. ABARIS SYSTEMS, 276 Oriental Pl, Lyndhurst, NJ 07071 (201) 939-0015.

LO COST Sensitive-Selective HF receiver system. Ideal/1st station set. Enhanced Novice 10/15/40/80m coverage. Send 2 stamps for free info. I. Megeff, KD2EF, 729 Lori Drive #101, Palm Springs, FL 33461.

HOBBY, EDUCATIONAL, INDUSTRIAL PRODUCTS. 70 kits. Amplifier, FM transistor, VU meter, door bell, alarm system, power supply. Send $3.00 to HOBBY ELECTRONIC, PO Box 1339, Claremont, NH 03743 or call (603) 543-0033.

COLLECTORS: Have Karl Pierson KP-81 communications receiver for sale. Complete system- receiver, speaker cabinet and book. Open to offers. Cal, KL7HEM, 10300 Silver Knolls, Reno, NV 89506.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

TRS80 4P/KANTRONICS UTU RTTY. Split-screen, 10 user keys, file transfer. Runs in Mod 4 (80 char) mode. $30 to COMMPRO RTTY, c/o KB6IC, 3711 Gayle Avenue, Omaha, NE 68123.

COMPUTERS COMMODORE 64 and XT repair. ABS (201) 758-6673.

CODE PROGRAMS. Apple/C-64. 31 modes, graphics, menus, wordprocessor, etc. LARESCO, POB 2018, 1200 Ring Road, Calumet City, IL 60409. (312) 891-3279.

SOLAR ELECTRIC PANELS and System Components. 1st quality for home or repeaters. Lowest prices in country. KA8DSS, RADIANT DISTRIBUTORS, 3900 Dursum, Ada, MI 49301. (616) 874-8899.

WA9GFR RF SOFTWARE $15.00 disk contains HF/VHF/UHF/L-BAND propagation and Smith Chart impedance matching programs. Specify Commodore-64 or MS-DOS BASIC. Lynn Gerig, 6417 Morgan RD, Monroeville, IN 46773.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photodocumentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

UHF PARTS. GaAs Fets, MMICs, trimmers, chip caps, teflon pcb, and other builder parts. SASE brings list. MICROWAVE COMPONENTS, 11216 Cape Cod, Taylor, MI 48180.

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

SHOW IT IN STYLE Full color QSL's by Smith Printing. From your prints/slides. Sample packet. SASE. 20420 Calhaven Drive, Saugus, CA 91350 (805) 251-7211.

WANTED: For Drake 4C the noise blanker 4NB (dead or alive). H. Schroefer, Dorfstr. 14, 3131 Gollau/Luechow, West Germany.

ANTIQUE RADIOS, schematics, tubes and literature. Send SASE to VRS (HR), 376 Cilley Rd, Manchester, NH 03103 for large list.

HAM MONITOR SCOPE Millen 90932 $85, audio signal generator HP200-CD $125, Precision E-200-C AM/FM signal generator $45, Yaesu FRG-7 general coverage receiver $125, Johnson phone patch $25, trade for TR-9000. K6KZT, 2255 Alexander, Los Osos, CA 93402.

YAESU OWNERS: Hundreds of modifications and improvements for your rig. Select the best from fourteen years of genuine top-rated Fox-Tango Newsletters by using our new 32-page Cumulative Index. Only $5 postpaid (cash or check) with $4 Rebate Certificate creditable toward Newsletter purchases. Includes famous Fox-Tango Filter and Accessories Lists. Milt Lowens, N4ML (Editor). Box 15944, W. Palm Beach, FL 33416. Telephone (305) 683-9587.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, New York 10538.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc, are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.

MASSACHUSETTS: April 19. Spring Flea at MIT. Sponsored by the MIT Electronics Research Society and W1XM/R. 10-4 PM. Albany and Main Streets, Cambridge. Buyers admission $1.50. Sellers $5. per space. Talk in on 146.52, 449.2 W1XM/R.

NEW YORK: June 14. The Hall of Science ARC Hamfest, New York Hall of Science parking lot, Flushing Meadow Park, 47-01-111 Street, Queens. 9 AM to 3 PM. Donations—buyers $4.00; sellers $6.00 per space. Talk in on 144.300 simplex link 223.600 repeat and 445.225 repeat. For information call Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schiffman, WB2YXB (718) 343-0172 evenings.

LOUISIANA: May 2 and 3* The Baton Rouge ARC Hamfest 50 and LA State Convention, Gym Armory, campus of LSU, Baton Rouge. Sat 8 AM—3 PM. Sun. 8 AM—2 PM. Free admission. Forums, ARRL speakers, Advanced swap tables reservations accepted. Dealers, tours, VE exams both days 9 AM. SASE, 610, check for $4.00 payable to ARRL/VEC to George Perry, W5LVX, 17424 Lady Constance, Greenwell Springs, LA 70739. Talk in on 146.19/79. For more info SASE to Rick Pourciau, NV5A, 879 Castle Kirk Dr, Baton Rouge, LA 70808. There will be Cajun food and entertainment Saturday nite. Come pass a good time!

PENNSYLVANIA: May 17. The Warminster ARC's 13th annual Hamfest, Middletown Grange Fairgrounds, Penns Park Rd, Wrightstown. Gates open 7 AM. 6 AM for Vendors. Donation $3.00. Non-hams and kids free. 8' indoor tables/power $5.00 by pre-registration only. Unlimited outdoor 8' space $5.00. Talk in on 147.69/09 and 146.52. For info and pre-registration contact Frank Charlton, KA3FBP, 1479 Kingsley Drive, Warminster, PA 18974. (215) 675-2549.

MARYLAND: May 24. Maryland FM Association's annual Ham fest, Howard County Fairgrounds, West Friendship, 30 miles west of Baltimore. Gates open 8 Am to 3 PM. Advance inside tables $7.00. At the door $10. Donation $3. Talk in on 146.16/76, 222.16/223.76 or 449.1/444.1 MHz. For tables or information: Jim Clifford, N3FBV, 7461 Terry Street, Ft. Meade, MD 20755. (301)674-4752.

COLORADO: May 16.Pikes Peak Radio Amateur Association 1987 Swapfest, Rustic Hills Mall, Palmer Park and Academy Blvd, Colorado Springs. 8:30 AM. Free admission. Tables $8.00 advance; $10.00 at door. VE testing. Talk in on 146.37/97. For information or reservations: Al, N0CMW (303) 4731660 or write PPRAA Swapfest, POB 1652, Colorado Springs, CO 80935.

ARIZONA: May 1-3. The Cochise Amateru Radio Association (CARA) will hold its 1987 Hamfest, club training facility, South Moson Road, Sierra Vista. Free tailgating. Talk in on 14y.52 or 146.16/.76. For information: Don Morgain, W7ACI, (602) 458-5293 or CARA, POB 1855, Sierra Vista, AZ 85636.

MISSOURI: May 17. The Western Illinois ARC will hold its 2nd annual Tri-State Swapfest, Haerr Field, Taylor. Tailgate flea market, aircraft exhibits, plane rides and VEC exams. Flea market setup 8 AM. General admission 9 AM. Talk in on 147.03 repeater. For information: Western Illinois ARC, POB 3132, Quincy, IL 62301

NEW HAMPSHIRE: May 15-17. The 13th annual Eastern VHF/UHF Conference, Rivier College, Nashua. For information contact Lewis D. Collins, W1GXT, Publicity Chairman, Eastern VHF/UHF/SHF conference, 10 Marshall Terrace, Wayland, MA 01778. (617) 358-2854 (6 to 10 PM EST)

NEW YORK: May 17. LIMARC will sponsor the ARRL Long Island Hamfair, New York Institute of Technology, Rt 25A, Northern Blvd, Old Westbury, NY. Sellers 7:30 AM. Buyers 9 AM. Outdoor tailgating. Sellers car space $5.00. General admission $3.00. Non-hams and kids admitted free. Talk in on 146.85. For information call Hank Wener, WB2ALW (516) 484-4322 evenings.

PENNSYLVANIA: June 7. The 33rd annual Breeze Shooters Hamfest, White Swan Amusement Park, Rt 60, near Pittsburgh International Airport. Free admission and Flea Market, family amusement park. 9 Am to 4 PM. For information and table reservations Bud Faulhaber, N3DOS, 1059 Balmoral Drive, Pittsburgh, PA 15237 (412) 366-5097.

OKLAHOMA: May 15-17. Green Country Hamfest, sponsored by the Broken Arrow and Tulsa ARCs, Vo-Tech SE Campus, 4600 S. Olive, Broken Arrow. Friday night mixer 6-10 PM at the Travelodge. Flea market and dealers open 9-5 Saturday and 9-01 Sunday. ARRL FCC exams. Children's room. Non-ham programs. Family BBQ dinner. For information contact Ron gamel, N5WX, (918) 663-0385 or write Green CountryHamfest, POB 4970, Tulsa, OK 74159.

MICHIGAN: May 16. Teh Wexaukee ARA's 27th annual Swap Shop, Wexford civic Arena, US 131 and 13th Street, Cadillac. 9 Am to 2 PM. Admission $3.00. Reefreshments available. Talk in on 146.97. For table reservations and more info call John Craddock, (616) 797-5491 or write Wexaukee ARA, POB 163, Cadillac, MI 49601

OHIO: May 17. TheAthens County ARA's 8th annual Hamfest, City Recrreation Center, East State Street, Athens. 8 AM to 3 PM. Admission $4.00. License exams. Send Form 610 and $4.35 check payable to ARRL/VEC to John Cornwell, NC8V, 101 Coventry Lane, Athens, OH 45701. Free paved outdoor flea market space. Bring your own tables. No reservations. Indoor space by advance registration. Contact Walt Jones, N8DDL, 17 Berkley Dr, Athens, OH 45701 (614) 593-7871. For general information Carl Denbow, KA8JXG, 63 Morris Ave, Athens, OH 45701.

PENNSYLVANIA: May 24. The Ephrata Area Repeater Society's 2nd annual Hamfest. Walk in VEC exams. Packet and ATV demos.

MICHIGAN: May 30. The Central Michigan Amateur Repeater Association (CMARA) 13th annual Hamfest, Midland Comunity Center, Midland. 8 AM to 1 PM. Admission $3. Food available. Dealers welcome. Packet radio, new/used Amateur electronics and equipment. License exams. Talk in on 147.00/60 Midland. For information CMARA Hamfest, POB 67, Midland, MI 48640. Please SASE. (517) 631-9228 evenings and weekends.

ILLINOIS: May 17. The Knox County Radio Club's annual Hamfest, Knox County Fairgrounds, Knoxville, IL. Gates open 7 AM. Building open 8 AM. Free flea market spaces available. ARRL/VE testing. For table reservations, pre-registration for testing and advanced tickets write Keith L. Watson, WB9KHL, 119 South Cherry Street #3, Galesburg, IL 61401-4527 or call (309) 342-3885 evenings.

NEW YORK: May 30. First Skaneateles Ham and Computer Fest, Allyn Arena, Jordan and Austin Streets. 8 AM to 5 PM. Vendors, ham gear and computer displays, exhibits. VE license exams. For reservations, info, motel list, contact Hank Bryant (315) 685-7658 or write Skaneateles Hamfest, 49 Elizabeth Street, Skaneateles, NY 13152.

ILLINOIS: May 17. The Chicago Amateur Radio Club's annual Mini-Hamfest, North Park Village, 5801 N. Pulaski, Chicago. 9 AM to 3 PM. Admission $1. Half table $3. Full table $5. Admits one seller. For info call 545-3622.

NEW JERSEY: May 9. The Cherryville Repeater Association's annual Hamfest, Hunterdon Central High School, Flemington. 8 AM to 4 PM. Indoor tables plus tailgating. FCC exams, forums displays and more. Talk in on 146.52, 147.975/.375. For further information or reservations call Bill Inkrote, K2NJ (201) 788-4080 or Don Mazak, NR2H (201) 782-1114.

COLORADO: June 20. The Grand Mesa Repeater Society will hold its 8th annual Western Slope Amateur Radio and Computer Swapfest, 9 AM to 4 PM, National Guard Armory, 482-28 Road, Grand Junction. Free admission. Swap tables $5.00 each. Indoor swapfest, Amateur Radio exams, auction and refreshments. Talk in on 146.22/.82 and 449.20. For tables or information SASE to Les Scott, NV0F, 2105 Yellowstone Rd, Grand Junction, CO 81503 or call (303) 242-5296.

CALIFORNIA: May 1, 2, and 3: The Fresno Amateur Radio Club will hold its 45th annual Hamfest, Fresno Airport Holiday Inn. Air conditioned dealer spaces and swap tables. FCC exams. Good programs and parking. Demonstrations and forums. Talk in on 146.34-94. For information: Glen T. Caine, Fresno ARC, PO Box 783, Fresno, CA 93712 or (209) 292-4611.

NEW YORK: May 3. The Suffolk County Radio Club's indoor/outdoor flea market, 8 AM to 2 PM, Republic Lodge No 1987, 585 Broadhollow Road, Rt. 110, Melville, L.I. General admission $3.00. Spouse and kids under 12 free. Indoor tables $10. each. Outdoor spaces $7.00 each. Includes one free admission. Talk in on 144.61/145.21 and 146.52 simplex. For information: Bill Sullivan, N2ETG (516) 689-9871 evenings.

NEW JERSEY: May 3. The Tri-County Radio Association's annual Indoor Hamfest/Flea Market, Passaic Township Community Center, Stirling. 9 AM to 3 PM. Donations $3.00. Tables $8.00; w/power $10.00. Reserved tailgating. Refreshments. Talk in on 147.855/.255, 146.52 and 444.975/449.975. For information: Dick Franklin, W2EUF, POB 182, Westfield, NJ 07090. (201) 232-5955.

ARKANSAS: May 2. The Northwest Arkansas ARC will hold its 7th annual Hamfest, Rogers Youth Center, 315 West Olive Street, Rogers. 8 AM to 4 PM. Doors open 6 AM for exhibitors. General admission and parking free. Nearby recreational areas and parking for RV's and campers. Talk in on 16/76 or 03/63. For information: Roy Milliren, AF5W, 2014 S. 16th Street, Rogers, AR 72756 (501) 636-6750.

VIRGINIA: May 3. The Lynchburg ARC will hold its annual Swapfest, Brookville High School grounds, Route 460 West, just outside Lynchburg. Rain or shine. Starts 9 AM. Admission $1.00. Tailgaters pay general admission plus $2.00. VE exams beginning 1 PM. Please pre-register. For more information write Lynchburg ARC, PO Box 4242, Lynchburg, VA 24502.

RHODE ISLAND: May 16. The RI Amateur FM Repeater Service will hold their annual Spring Flea Market and Auction, American Legion Fairmount Post 85, 870 River Street, Woonsocket. Flea market opens 9 AM and spaces are $5.00 each. Auction from noon to 5 PM. Free admission. Food and beverages available. Talk in on 34/94 and 52 simplex. For information: Rick Fairweather, K1KYI, Box 591, Harrisville, RI 02830 or call (401) 56:8-0566, 7-9 PM.

CONNECTICUT: May 31. The Newington Amateur Radio League will hold its fourth annual Flea Market, Newington High School, Willard Avenue, Newington. 9 AM to 2 PM. New/used ham gear, computer equipment. Admission $2.00 at the door. Indoor tables $8.50, $10 after May 23. Tailgaters $5. Guided tours of ARRL Hq. Amateur Radio exams. Talk in on 146.52 and W1AW/R, 144.85/145.45 and 223.24/224.84. For exam information or table reservations: Les Andrew, KA1KRP, 23 Grove St, West Hartford, CT 06110. (203) 523-0453. Please SASE.

ILLINOIS: May 17. The Kankakee Area Radio Society's annual Hamfest, Kankakee County Fairgrounds, 8 AM to 4 PM. Admission $2.50 advance; $3.00 at the door. FCC and ARRL booths.Free flea market tables. Free parking. Talk in on 146.34/94. For information: KARS c/o Frank DalCanton, KA9PWW, RR 1, Box 361, Chebanse, IL 60922. (815) 932-6703 after 5 PM CST or (815) 937-2452 before 5 PM.

MINNESOTA: May 9. The Arrowhead Radio Amateur Club's Swapfest '87, First United Methodist Church, 230 East Skyline Parkway, Duluth. 10 AM to 3 PM. Admission $4.00. 4' tables $5.00. License exams 9 AM. For Amateur exams contact Eddy Lonnstrom, N9DHG, 2026 Baxter Ave, Superior, WI 54880 (715) 392-2415. General information: Ron Carlson, K0BR, 5128 Wyoming Street, Duluth, MN 55804 (218) 525-6860.

SOUTH CAROLINA: May 2 and 3. The Blue Ridge Amateur Radio Society's 48th annual Greenville Hamfest and Electronic Flea Market, American Legion Fairgrounds, Greenville. Saturday 8 AM to 5 PM. Sunday 8 AM to 3 PM. Admission $3.50 advance and $5.00 at gate. Indoor/outdoor flea market, license exams, free parking, food. For tickets or information SASE to Blue Ridge ARA, PO Box 6751, Greenville, SC 29606.

NEW HAMPSHIRE: May 9. New England's favorite—The Hosstraders Spring Tailgate Swapfest, Deerfield Fairgrounds. Admission $2.00 per person including sellers and commercial dealers. Friday night camping at nominal fee only after 4 PM. Profits benefit Shriners' Burns Hospital. Last year's gift over $13,500! For map, SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

PENNSYLVANIA: May 3. The Delaware County ARA is sponsoring their 8th annual Hamfest, Drexel Hill Middle School, State Road and Penn Avenue, Drexel Hill. Doors open 8 AM. Setup 7 AM. Admission $3. Reserved indoor tables/elec. available for $3.00 per space. License exams. Refreshments available. Talk in on 147.96/36, 224.5 and 146.52. For registration and information write Hamfest, DCARA, PO Bkox 236, Springfield, PA 19064 or call Barbara, N3DLG (215) 535-1616.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.

VIRGINIA: June 7. The Ole Virginia Hams present the Annual Manassas Hamfest, Prince William County Fairgrounds. 8 AM to 4 PM. General admission $4.00. Children under 12 free. Tailgating $5.00/space. Dealers, ARRL booth, CW proficiency award. Talk in on 146.37/97, 146.52. For information write: Ole Virginia Hams ARC, POB 1255, Manassa, VA 22110. John Gunsett, KI4VP (703) 361-5255 or Gene Roberts, N4HFW (703) 361-3983.

NEW JERSEY: May 17. OBRA Annual Festival. Old Bridge Civic Center Arena, Cottrel Road and Hwy 516, Old Bridge. Sellers 6 AM $12.00. Buyers 8 AM, $5.00. Tailgating $8.00. FCC exams, pre-registration suggested. Walks in 9 AM. Testing 10 AM. Talk in on 7.12/7.72. For information N2DHN.

NORTH CAROLINA: May 23. The Durham FM Association's annual Hamfest, Lower rear deck South Square Mall, Durham. 8 Am to 4 PM. FCC exams, vendors and free tailgating. Talk in on 147.825/.225, WA4WTX.

MICHIGAN: June 7. The Chelsea Swap and Shop, Chelsea Fairgrounds, Chelsea. Sellers 5 AM. Buyers 8 AM to 1 PM. Donation $2.50 advance and $3.00 at the gate. Children under 12 and non-ham spouses free. Talk in on Chelsea Repeater 146.980. For information: Robert Schantz, 416 Wilkinson St, Chelsea, MI 48118. (313) 475-1795.

WISCONSIN: May 2. The Ozaukee Radio Club will sponsor its 8th annual Cedarburg Swapfest, Circle B Recreation Center, Highway 60 and County I, Cedarburg. 8 Am to 1 PM. Admission $2.00 advance, $3.00 at the door. 4' tables $3.00 each. Food and refreshments available. For tickets, reservations or information SASE to 1987 ORC Swapfest, 101 E. Clay Street, Saukville, WI 53080 or phone (414) 284-3271.

NEW JERSEY May 17. The Bergen County ARA is sponsoring its Spring Hamfest, Bergen Community College, 400 Paramus Road, Paramus. 8 to 4 PM. Rain or shine. Buyers free. Sellers $5 per space, tailgate only. License exams. Talk in on 146.19/79 and .520 simplex. Forfurther information: Jim, KK2U (201) 445-2855, 444 Berkshire Rd, Ridgewood, NJ 07450.

OPERATING EVENTS

"Things to do . . ."

May 2. The Louisville A.R.T.S. will operate "Run For The Roses" under the call W4CN. 2400 to 0500 May 1 and 1300 to 1700 May 2. For a commemorative certificate send QSL and 39 cents SASE to ARTS Club, W4CN, POB 7391, Louisville, KY 40207.

May 9. The Laurel ARC will operate special event station W3GFS from 1400Z to 2000Z to help celebrate the 4th annual Main Street Festival in Historic Laurel, MD. SASE for 8x11 certificate. QSL to LARC, POB 1436, Laurel, MD 20707.

May 23: The Old Barney ARC os Southern Ocean County, New Jersey announces a special event Amateur Radio operation commemorating the 75th anniversary of the start of construction of the Tuckerton Wireless Tower. 00001Z May 23 thru 2359Z May 24. For information contact Bob Schenck, N2OO, Publicity Manager, OBARC. (609) 296-0307

May 23, 24, 30. The Carroll County ARC will operate K3PZN in celebration of Carroll County's Sesquicentennial. For 8x11 certificate send QSL and SASE to Carroll County ARC, POB 2099, Westminster, MD 21157.

ARMED FORCES DAY May 16 1987. In recognition of the 38th anniversary of this event, ARS W4ODR aboard NAS Memphis, Millington, Tennessee will be operated by sailors and marines from 1300Z to 2300Z. For additional information Station Custodian, Senior Chief Petty Officer Bob Donan, KA4FAL, (901) 872-2007.

May 16. The Charleston Amateur Radio Society will operate Special Event Station from the deck of the aircraft carrier USS Yorktown CV-10 located in Charleston, SC. Callsign WA4USN. 1000Z to 2200Z. For a special QSL card with photo of the ship (to confirmed contacts) SASE to Special Event Station, 346 Parkdale Dr, Charleston, SC 29407.

THE FOUNDATION FOR AMATEUR RADIO, INC. plans to award 26 scholarships for academic year 1987-88 to assist licensed Radio Amateurs who plan to pursue a full-time course of studies beyond high school and are enrolled or have been accepted by an accredited university, college or technical school. For further information write FAR Scholarships, 6903 Rhode Island Avenue, College Park, MD 20740 prior to May 31, 1987.

ARMED FORCES DAY 1987 May 16. The 38th annual Armed Forces Day Communication Test. Traditional military-to-Amateur cross band operation and broadcast of the Secretary of Defense message are the featured highlights and include operations in CW, SSB and RTTY.

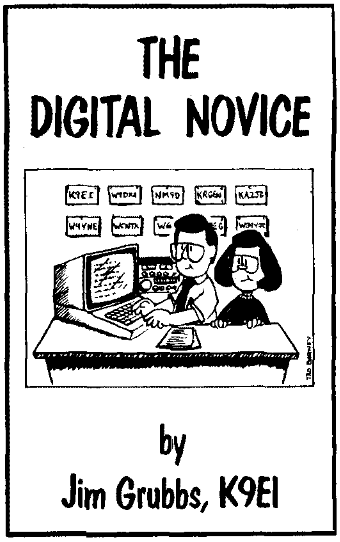
book REVIEW

the digital novice

The man who helped thousands of Amateurs *Get ***Connected to Packet Radio* has done it again. In *The Digital Novice*, author Jim Grubbs, K9EI, explains the fundamentals of digital communications with authority, clarity, simplicity, and wit.

Warning: This is a *very* basic book that covers, rather lightly — but in detail sufficient for most beginners — the whole range of Amateur digital communications, from what Jim calls "cave-dweller digital" to spread spectrum and transmission, via packet radio, of *animated* visual images.

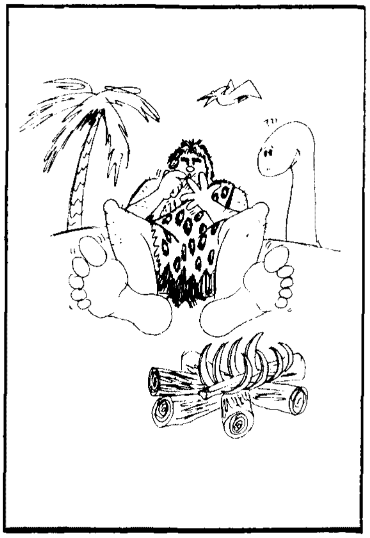
Why are we recommending it to readers of *ham radio* with enthusiasm? Well, for one thing, we know that some readers are dyed-in-the-wool analog types to whom digital technology is something of a mystery. Others understand the technology, but want to acquire an overview of



New from QSKY. *The Digital Novice* introduces beginners — regardless of license class — to digital communications.

equipment available, with an eye toward becoming active in one digital mode or another.

But there's a better reason to read this book. There are some 80,000 Novices out there, and the new Novice enhancement regulations (which Jim spells out in comprehensive, up-to-the-minute detail) will certainly bring in more. Now these people will no doubt expect you, with your higher class of license, to know *everything*. What's more, they're going to be looking to you not only to know it all, but to explain it, too — in terms they can understand — or at least direct them toward appropriate sources of information.



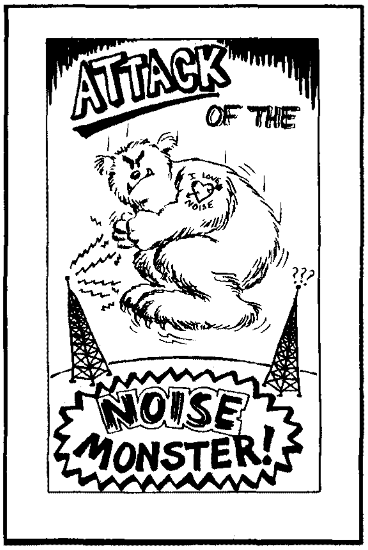
"Cave Dweller Digital" was earliest form of digital communications.

The Digital Novice helps you answer questions like "What exactly is AMTOR?", "How is packet different from earlier digital techniques like RTTY and ASCII?", and "What interface should I buy?" without having your face turn red or getting your tongue all tied up in embarrassing knots — and *without confounding the questioner*. No doubt you can answer all sorts of questions about digital techniques, even roused from a deep sleep after driving home from Dayton for two days straight. But wouldn't it be convenient to just point to *The Digital Novice*, roll over, and go back to sleep?

This isn't another book about packet radio, by the way, or a book about computers, though there's enough about computers to form a solid basis for understanding the material. It isn't "a computer book." It is a book you can give without reservation to any interested beginner, regardless of age. Though it's written for adults, I wouldn't hesitate to give it to a bright, highly motivated eighth-grader. There's no question about it: Jim is a born communicator, a writer who knows his audience and speaks to them in language they understand, simplifying complex subjects without ever "talking down." What might cause us to be rendered essentially inarticulate (as a function of knowing either too much or too little), he explains with refreshing simplicity. As Jim points out, technically knowledgable people aren't necessarily the best "missionaries for the new technologies." Not convinced? Quick: explain spread spectrum in language a Novice can understand.

Describing equipment available, Jim names names and comments, with candor, on every piece of hardware about which Novices need to know, citing advantages and disadvantages of each. Though addresses are not included, they're all here: AEA, GLB, MFJ, Kantronics, Packeterm — and, of course, TAPR and Vancouver as well.

The text is supplemented with an ample glossary plus appendices listing the various digital codes (Morse, Baudot, AMTOR, ASCII). There's a clever little bonus at the end, too: to give readers an opportunity to check how well they've retained what they've read, Jim has included a 33-question test covering topics discussed in the book. Answers are included, plus references to page numbers where subjects covered by questions can be found. Score 80 or better (on your honor), send Jim an SASE, and — just for fun — he'll send you a certificate attesting to your status as an official "Digital Novice."



"Noise Monster" substantiates author's assertion that noise is the natural enemy of digital communications.

Ted Barney's cartoons go a long way toward lightening up *The Digital Novice*. I was pleased, too, by Jim's conscious (but never self-conscious or heavy-handed) effort to ensure gender fairness throughout the text; his deft use of pronouns may help women entering Amateur Radio through the digital modes feel more welcome.

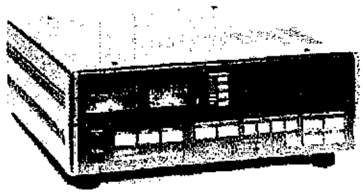
The Digital Novice will be released at this year's Dayton Hamvention®, you can meet the author at his booth (QSKY Publishing, No. 358) if you're there. You can also catch his presentation on Sunday morning at 9:30 AM. Whether or not you make it to Dayton this year, you can order your copy of *The Digital Novice* from Ham Radio's Bookstore Store for $9.95 plus $3.50 shipping and handling.

— KA1LBO

NEW products

solid-state linear amplifier

The latest addition to the Yaesu product line — the new FL-7000 Solid State Linear Amplifier for the 160 through 15 meter bands — features an automatic antenna tuner with automatic band-switching when used with the Yaesu FT-757GX, FT-767GX, or FT-980 transceivers. Antenna switching is also automatic when using the FAS-1-4R remote antenna selector. Power output is 1200 watts, for approximately 70 watts input. A protection circuit prohibits operation with high SWR until the antenna tuner completes matching process. Thermostatically controlled dual fans run even when the amplifier is turned off, if needed for dissipation of heat.



For details, contact Yaesu U.S.A. Amateur Products Division, 17210 Edwards Road, Cerritos, California 90701.

Circle #312 on Reader Service Card.

new dual-port tnc, personal mailbox upgrade

The new KPC-4 Dual Port Communicator from Kantronics features two fully-functional VHF packet ports, digipeating on each port, VHF gateway between ports, and an RS-232 computer port. Digipeating and gateway operations occur simultaneously while you're connected on one or both ports. You can bridge two frequencies on one band and operate crossbands.

The KPC-4's RS-232/TTL terminal interfacing provides universal compatibility to all computers, including Commodores and PC compatibles. Stream switching provides for access to both radio ports, each of which supports AX.25.

Priced at $329.00, the KPC-4 contains the popular Personal Packet Mailbox™ feature (optional on all other Kantronics Packet Communicators), a 256K EPROM that allows you (and others) to leave and collect messages on

NEW products

your system. All other functions of your packet unit continue to be available at the same time. Established and operated from your keyboard, the mailbox uses familiar commands such as SEND, LIST, READ, KILL, and BYE. The number of messages is limited only by the amount of RAM available in your packet unit.

The Personal Packet Mailbox option is currently available for the KAM (Kantronics All Mode), the PKC-1, the KPC-2, and the KPC-2400. To add the Personal Packet Mailbox option to your Kantronics packet unit, contact Kantronics or an authorized Kantronics dealer. The option retails for $39.95 (plus $2.50 for shipping if ordering through Kantronics), and includes a replacement plug-in EPROM and an installation/operations manual.

For further information, contact Kantronics, Inc., 1202 E. 23 Street, Lawrence, Kansas 66046.

Circle #315 on Reader Service Card.

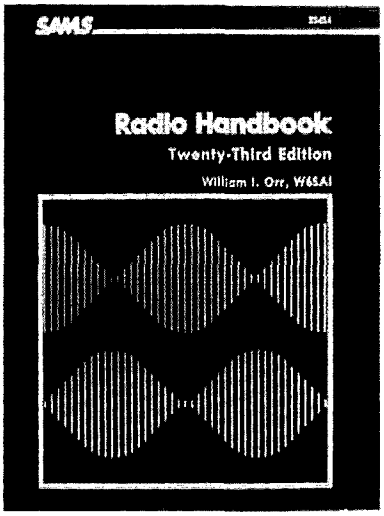
new *Radio Handbook*

The 23rd Edition of Bill Orr, W6SAI's, *Radio Handbook* has just been released by Howard W. Sams & Company.

Completely revised and updated, this edition contains new material reflecting the latest developments in technology, covering everything from HF-VHF amplifier design to interference reduction for VCRs and video disc players.

Readers will find schematics, photos, construction diagrams, tables, and charts right at their fingertips, for expert guidance and instant reference. Specific topics addressed include an introduction to Amateur Radio communications; fundamental of communications receivers; fm and repeaters; mobile, portable, and marine equipment; radio and television interference; equipment design, components, and controls; VHF and UHF antennas; and transmission lines and matching systems.

Licensed as a radio amateur in 1934, Bill has authored or co-authored many books. Editor of the *Radio Handbook* since 1955, he's written



hundreds of technical articles, including a monthly column in *ham radio*.

Bill Orr's *Radio Handbook*, 23rd Edition, (640 pages, hardbound) retails for $26.95 and is available from Ham Radio's Bookstore, Greenville, New Hampshire 03048. Add $3.50 for shipping and handling.

new 900-MHz antennas

Two new 900-MHz antennas available from NCG are specifically designed for operation in the 902-928 MHz band.

The anodized black Model CMW-202N mobile antenna, a 5-dB gain antenna capable of a maximum of 30 watts of drive power, uses a magnetic mount with a double coil whip. The 900-MHz base/repeater antenna, model CFC7-71, is a collinear fiberglass antenna with a gain of 7.14 dB and maximum power capability of 50 watts. Mast mounting brackets and hardware is included.

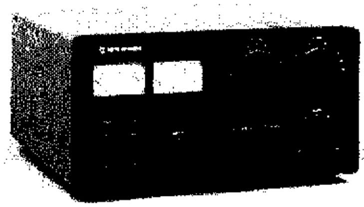
For information, contact NCG Company, 1275 N. Grove Street, Anaheim, California 92806.

Circle #310 on Reader Service Card.

new hf amplifier

Tokyo Hy-Power Labs' HL-2K/A is a compact hf amplifier utilizing the popular 3-500Z transmitting tubes. Similar to their HL-1K/A, it features a built-in power supply with a heavy-duty transformer that permits continuous key-down operation. The amplifier is equipped with two large panel meters: one monitors plate current, and the other can be switched to read plate voltage, grid current, or power output. A delayed cooling fan system protects the tubes for a timed period after the power has been turned off.

NEW products



The price of the HL-2K/A is $1695. For details, contact ENCOMM, Inc., 1506 Capital, Plano, Texas 75074.

Circle #309 on Reader Service Card.

Lunar returns to market

Lunar Industries, Inc., of San Diego has re-entered the Amateur Radio market with its well-known line of VHF and UHF preamps and VHF power amps, and has introduced a new line of products scheduled for production early this year. Glenn Rattmann, K6NA, heads the marketing effort.

Lunar recently moved into larger facilities in order to accommodate expanded production of Amateur and commercial communications and television equipment. A network of select dealers is being established and inquiries are encouraged. For details, contact K6NA at Lunar Industries, Inc., 7930 Arjons Drive, San Diego, California 92126.

Circle #308 on Reader Service Card.

cordless tool for soldering, welding, heat shrinking

The Ultratorch, available now from Jensen Tools, is a compact, cordless combination soldering iron, flameless heat tool, and torch. The Ultratorch burns ordinary butane lighter fuel to generate infra-red and ultra infra-red heat by means of a catalytic combustion system. Temperature can be adjusted from 394 degrees to 2372 degrees. Normal settings range from 394 degrees to 932 degrees F for soldering; to 1292 degrees for heat shrinking; and to 2372 degrees for blazing, welding, and other high-heat applications. Soldering/heat ejector, torch ejector, tapered needle soldering tip, heat tip, solder

NEW products

sponge, tip cleaner and spanner wrench are all included.

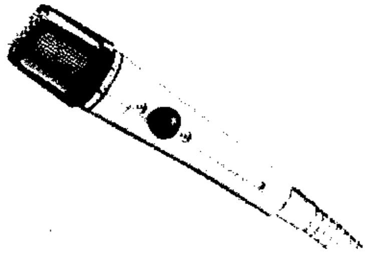
For more information and free catalog, contact Jensen Tools, Inc., 7815 S. 46th Street, Phoenix, Arizona 85044.

Circle #307 on Reader Service Card.

new mic

Shure Brothers Inc. has introduced the Shure Prologue 2L, an economical dynamic microphone for gooseneck applications.

Priced at $40, the Prologue 2L provides a wide range frequency response with a low-end rolloff and high-end presence boost for intelligibility and clarity. Other features include a long-life, easy-



access momentary push-to-talk switch, a tight cardioid polar pattern for effective rejection of feedback and background noise and chrome-plated metal casing.

For information, contact Shure Brothers Inc., Customer Services Department, 222 Hartrey Avenue, Evanston, Illinois 60202-3696.

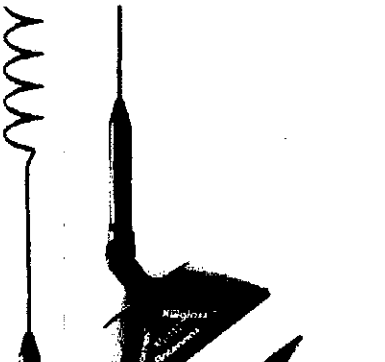
Circle #306 on Reader Service Card.

two new Kulglass™ antennas

Larsen Electronics has added two new models to its line of patented Kulglass antennas: the KG-440 and the KG-900. The two new antennas offer the same features as the earlier KG-450 and KG-825, but extend Kulglass™ convenience and performance to the 440-450 and 902-928 MHz bands.

The Kulglass tuning assembly is placed on the outside surface of the glass — a car windshield, for example. This allows a low-impedance power transfer through the glass.

The KG-440 is based on a single half-wave design that offers unity gain performance without a ground plane and up to 2.4-dB gain in a typical vehicle installation.



The antennas are fully adjustable to vertical for practically any window angle. This permits their resonant design to attain a low VSWR, a low radiation angle, and maximum omnidirectional range without a ground plane. This is especially important with the KG-900 because

NEW products

of the multipath signals and low power used in this band.

Both antennas feature a removable whip (which can come in handy in zero clearance situations, such as at the car wash) and Larsen's exclusive Kulrod T™ plating. The antenna kits include 14 feet of premium RG-58 A/U dual-shield, low-loss coax and choice of connectors.

For further information, contact Larsen Electronics, P.O. Box 1799, Vancouver, Washington 98668.

Circle #305 on Reader Service Card.

HF/VHF packet radio controller with tuning indicator

MFJ Enterprises' latest TAPR TNC-2 clone, the MFJ-1274, ($169.95) works not only for VHF but also for HF, OSCAR, and other non-fm packet. MFJ has made the 1274 modem-selectable for both VHF and HF operation, added their precision 20-segment LED tuning indicator, a TTL serial port, an easily replaceable lithium battery for memory back-up, and a new cabinet.

All you need to enjoy packet radio is an MFJ-1274, your rig, and any home computer with an RS-232 or TTL serial port and terminal program.

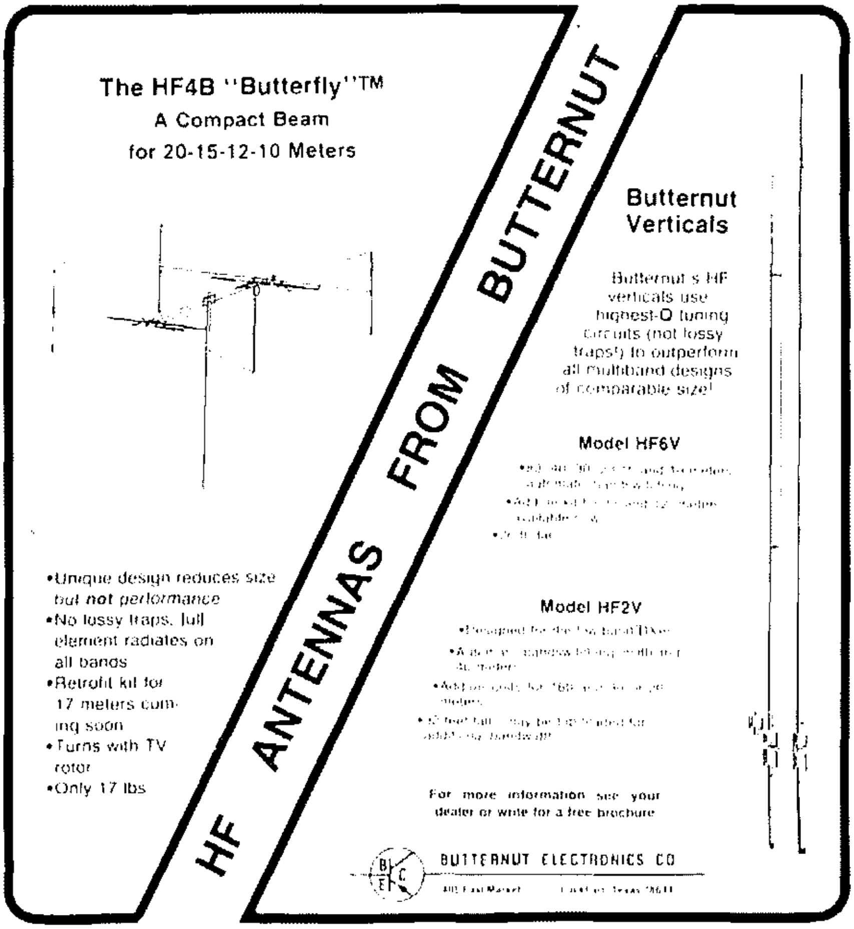
If you have a Commodore 64, 128 or VIC-20 you can use MFJ's optional Starter Pack to get on the air immediately. The Starter Pack includes interfacing cable, terminal software on disk or tape and complete instructions . . . everything you need to get on packet radio. The MFJ-1282 (disk) and the MFJ-1283 (tape) are $19.95 each.

With the MFJ-1274, you'll never have to worry about your TNC's becoming obsolete because you change computers or because packet radio standards change. You can use any computer with an RS-232 serial port with an appropriate terminal program. If packet radio standards change, software updates will be made available as TAPR releases them.

With the addition of a suitable external modem, speeds in excess of 56 kilobaud are possible.

The MFJ 1274 features AX.25 Level 2 Version 2 software, hardware HDLC for full duplex, true Data Carrier Detect for HF, multiple connects, 256K EPROM, 16K RAM (expandable to 32K with optional EPROM), simple operation, and socketed ICs.

You get an easy-to-read manual, a cable to connect your transceiver (you have to add a connector for your particular radio), a connector for



NEW products

the TTL serial port and a power supply for 110 VAC operation (you can use 12 VDC for portable, remote or mobile operation).

The MFJ-1274 comes with a double guarantee. If ordered directly from MFJ, it may be returned within 30 days for a prompt refund, less shipping. The MFJ-1274 is also covered by MFJ's one-year unconditional guarantee.

For more information, contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, Mississippi 39762.

Circle #311 on Reader Service Card.

computer control of rf monitoring

The CR 202, a sophisticated new receiver distributed by Ace Communications, allows monitoring of any frequency from 25 to 550 MHz, plus 800 to 1300 MHz.

With both narrow and wide band reception modes in fm and also a-m, the receiver, priced at $445, is excellent for general monitoring and surveillance reception of a wide variety of services.

Uses for the unit include general off-air monitoring, spot frequency monitoring and stength measurement, selective multi-frequency analysis, spectrum surveillance, and detection of unwanted transmissions.

An optional digital control accessory permits the user to interface the receiver to any computer equipped with a standard RS-232C port. The resulting computer control permits virtually unlimited channel monitoring and activity analysis with normal communications, text editing, and data base software. A dedicated menu driver software package and a full line of accessories are available.

For information, contact Ace Communications, Monitor Division, 10707 East 106th Street, Indianapolis, Indiana 46256.

Circle #304 on Reader Service Card.

new battery packs

Two new battery packs for King Radio Corporation products are available from Centurion International Inc. No. KR0105 is a 9.6-volt, 800 MAH nickel-cadmium rechargeable battery pack; No. AL0514 is a 13.5-volt, 2100 MAH throwaway alkaline pack. For prices and details, contact Centurion International, Inc., P.O. Box 82846, Lincoln, Nebraska 68501.

Circle #303 on Reader Service Card.

NEW products

Super ComShack 64™

On January 1, 1987, Engineering Consulting shipped the first Super Com Shacks 64's to previous purchasers of the Com Shack 64 Duplex/Simplex ham shack and repeater controllers. The first units shipped were designed to upgrade existing systems to allow the features found in the new "Super" version.

New features of the "Super" version include a unique code practice mode, speed dial data entry of command strings consisting of multiple commands, and nine complete sets of access codes which can be changed at any time remotely from an HT or telephone, allowing instant repeater access code changes, which can reduce unauthorized use of repeater functions. The system autopatch supports up to 310 stored telephone numbers; ten emergency numbers may be accessed instantly with two digit commands. The balance of the 300 numbers may be stored via touchtone and recalled at any time.

Three hundred callsigns can be programmed into the new Super ComShack. In the "directed page mode," an unlicensed person can call the repeater telephone line and receive a voice message identifying the repeater and requesting input of a three-digit code. A valid code will voice-page the selected callsign over the repeater. If the page message is answered by the Amateur with the proper answer code, the calling party is then put "on the repeater" and a normal conversation can take place. If a control operator needs to gain access to the repeater, it can be done via telephone or touchtones from an HT.

The Super ComShack system offers dual remote base capability, which allows both UHF and HF radios to be input or linked to the main repeater. Total control of the link radio is provided through the use of serial data. Software is included to control the Yaesu FT-757, FT767, FT980, and FT-727; the Kenwood TS440 and TS940; the TM711/811; and Icom's IC735 transceivers. New radios are being added as manufacturers provide samples for serial data programs to be tested.

A new system — dubbed the "Ultra" — is currently under development. Compatible with the "Super," the "Ultra" will link several systems together, allow for Packet input, and incorporate other advanced features.

The Super ComShack is available from Engineering Consulting, 583 Candlewood Street, Brea, California 92621.

solder 14 different metals — with a match

Quick Silver is a new silver-bearing bonding paste that flows at 430 degrees F using a match, butane lighter, or soldering gun — not 1200 to 1300 degrees F, as in conventional silver soldering. Quick Silver has a tensile strength of 18,000 to 22,000 psi compared to only lead solder's 3,000 psi.

Quick Silver is furnished in a syringe-type applicator that enables the user to apply the paste first and then hold and apply heat. Suitable for electrical work where high conductivity and strength are required, it conforms to pure food laws (i.e. contains no lead, zinc, cadmium or antimony) and provides a good color match to stainless steel. It won't darken or tarnish.

Quick Silver can be used on brass, bronze, chrome-plated steel, chrome-plated copper, copper, gold-filled and gold-plated materials, molybdenum, nickel silver, silver, stainless steel, steel, sterling silver, 800 silver, tin, and zinc. Priced at $9.95 plus $2.00 postage and handling, it's available from E.L. Jones Company, P.O. Box 849, Sanford, North Carolina 27330.

Circle #302 on Reader Service Card.

DX nets, beam headings

DX Net List Around the World provides full information about all active DX nets and updates the DX Net List for 1987. Previous editions of the list — with information about DX Nets that might be reactivated as conditions allow — are still available.

DX Beam Headings Around the World shows bearing, distance in miles and kilometers, and reverse bearing for your QSO partner), for both shortpath and longpath, for more than 450 locations throughout the world. Special care has been taken for the Antarctic, USA, USSR, the Peoples Republic of China, and the Pacific Ocean.

For information, contact Ing. Christian Hohenwallner, OE2CHN, Gneisfeldstrasse 5, A-5020 Salzburg, Austria or Dieter Konrad, OE2DYL, Bessarabierstrasse 39, A-5020 Salzburg, Austria.

JUNE 1987 / $2.50

new column —
Elmer's Notebook
by Tom McMullen, W1SL

ham radio magazine

compact cw transceiver for 20 meters

hr

focus on communications technology

ham radio

magazine

JUNE 1987

volume 20, number 6

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95, two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00; three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service): one year, $37.00
All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

international subscription agents: page 91

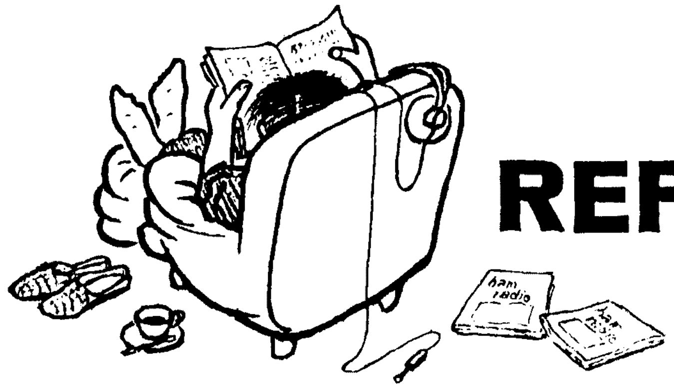
Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio* are available to the blind and physically handicapped from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

**Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498**

contents



REFLECTIONS

a whole new generation of "designers"

I just read an honest, provocative article in the April, 1987 issue of *Folio*, a magazine for people who publish and produce magazines, about how some people expect to become editors and publishers simply by purchasing desktop publishing systems. In short, the author of that article said — and I fully agree — that a piece of equipment and some software do not an editor make.

I'm wondering if the same thing can be said about electrical circuit designers. Take a PC and any of your better interactive design software, be it for filters, amplifier stages, or receivers. Add some form of schematic capture capability — and voila! A full-fledged designer!

Well, maybe . . . .

Someone with reasonable intelligence (i.e., able to form cause-and-effect conclusions), when provided with a PC and some interactive software, will probably generate some pretty decent designs. You might even get those designs from him a lot faster than you'd get them from the generation of designers and engineers of which I consider myself a part.

For example, let's say you buy a relatively sophisticated piece of filter synthesis software with a well-thought-out, user-friendly, menu-driven program. A basic circuit is provided as part of a learning tutorial. Hit one of the function keys and the circuit response pops up on the screen, replete with MHz and dB. If the rejection or bandwidth or ripple isn't exactly what you want, back you go to the original menu; you simply turn the knob and *watch* the response take all different shapes.

Depending upon the sophistication of the software, you might have to do no more than enter your wish list; the computer will not only provide the circuit topology (after going through all the possible choices — Chebyshev, Butterworth, Elliptical, Gaussian, etc.) quietly and rapidly, but will determine the number of poles, matching sections, and component values as well. Of course, it's possible that your wish list will exceed even Fano's limitation (a fundamental mathematical relationship which says, in essence, that you can't get something for nothing). But then if the software is worth its salt, it will gently remind you that what you desire isn't exactly possible, and ask whether you might be willing to consider modifying the parameters to conform just a little bit more with reality.

Basically, then, what we have is a new generation of designers who don't necessarily need to rely on a storehouse of knowledge about resistors that *aren't*, coils that need to be "opened up" just a little more, box covers that *do* have an effect, and all other the peculiarities one can encounter in the analog world.

Though this makes me feel somewhat like a relic (I still enjoy "hands-on" designing), I suspect many of us older (read that "more mature") Radio Amateurs share the same feeling. However, in the case of circuit design software, I believe real progress has occurred: tools have been developed by the older generation that can be used by the younger generation to effect better and more efficient designs more quickly than ever before.

Rich Rosen, K2RR
Editor-in-Chief

comments

groundplane antenna

Dear HR:

The original "groundplane antenna" was not developed by Brown, Epstein, and Lewis in the late 1930s, as generally published and last mentioned in *ham radio* ["The Offset Drooper — An Improved Gound Plane," by Woodrow Smith, W6BCX, February, 1986, page 43].

This VHF/UHF antenna was invented several years before in France by Maurice Ponte (French patent No. 764.473, 1933) with all the main items such as elevated feedpoint, coaxial feeding, and radials.

The "groundplane" for preventing undesired radiation from feedline was described either as a disk 1/2-wave in diameter or as a number of horizontal 1/4-wave radials.

This invention was also known and patented in the United Kingdom and in the United States (United Kingdom patent No. 414,296, applied for in 1934; United States patent No. 2,026,652, applied for in 1933 and granted in 1936).

Two remarkable early contributions to the groundplane antenna development should be noted: a base reactance compensation for reduction of amplitude and phase distortion for television application (Germany, 1936) and tuned radials, either with coiled conductors and series capacitances or with bent or encircled arms tunable for series resonance (United Kingdom, 1937/38).

This present information about the early history of groundplane, however, does not diminish the importance of Dr. Brown's role as a great American inventor and antenna specialist. His remarkable works, known worldwide, include: *Earth Currents* (1933), *Turnstile* (1935), *Broadcast Antennas* (1935), *Multifrequency Antenna* (1936), *Ground Systems and Antenna Efficiency* (1937), *Directional Antennas* (1937, *Square Antenna* (1938), *Rotary Beam* (1940), *Collinear Antenna* (1941), *Duplex Balancer* (1942), and *RF Wattmeter* (1943).

Alois Krischke, DJ0TR/OE8AK
Munich, West Germany

kudos > kantronics

Dear HR:

With all of the less than desirable business practices going on in this world, it is with pleasure that I relate a good experience with you.

After purchasing a used Kantronics UTU Universal Terminal Unit, I discovered that there was a problem with "handshaking" between the UTU and the computer. After inserting a breakout box between the two, I found that the UTU was not sending a CTS (Clear To Send) signal to the computer. This prevented the computer from sending anything to the UTU, because as far as the computer was concerned, the UTU just wasn't ready.

I called Kantronics and spoke with their service technician, who informed me that I was using an older version of the firmware (version 1.0) and said that if I would give him my address, he would send me out the updated version (1.3). Although I informed him that I had purchased this unit used, he replied that it was company policy to correct any manufacturing errors. The replacement EPROM was received about four days later, and it works just fine.

Thus, in this day of the quick buck, it is a pleasure to announce to the world that there are still quality firms out there doing business. Please pass along the word, and send them more business!

Rick Mainhart, WB3EXR
Mystic, Connecticut 06355

a compact 20-meter CW transceiver

Pack a private DX-pedition in a *very* small bag

DX-ing from another part of the world is something most of us would like to try, but packing those extra suitcases full of equipment can take much of the joy out of traveling. My solution to this problem was to choose a favorable band and mode, and then design a super-compact station that would slip into my suitcase without displacing more essential items. I settled on the 20-meter band because it's open most of the time, and because portable antennas for that band are easy to pack and erect. I chose CW because it provides the best opportunity for reliable long-range communications on low power.

The *CW Travelradio*, described in this article, is what resulted. The entire package measures 1.5 x 4.5 x 6.0 inches and weighs just *1.5* pounds. The receiver is a conventional superhet with AGC and a switchable CW audio-bandpass filter; the choice of speaker or headphone operation is yours. The transmitter delivers 12 to 15 watts to the antenna, and features sidetone and semi-break-in. The VFO range covers the bottom 100 kHz of the band, where virtually all CW and most RTTY operation takes place.

circuit description

To expedite the design, I reworked board art from an existing 1-watt SSB exciter to make a basic transceiver circuit board. I then designed a control board to provide shaped keying, semi-break-in T/R switching, and sidetone generation. I completed the package by adding a simple two-stage audio-bandpass CW filter and a 15-watt class C PA.

The receiver is an updated version of previously published designs.[1,2] Double-balanced mixer U1 (see **fig. 1**) amplifies and converts 14-MHz signals to 9 MHz, which are filtered through FL-1 and fed to i-f amplifier U2. The gain of U2 is controlled by an audio-derived AGC. U3 is a DBM product detector. U4 amplifies received signals and sidetone to speaker level, and provides AGC drive to dc amplifier circuit Q1, Q2. U4 runs at full gain, with speaker and headphone volume controlled "downstream" via R1. This arrangement permits full AGC action at all gain control settings.

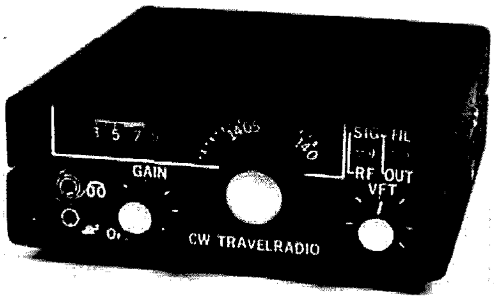
Transmit mixer U5 combines BFO and VFO drive to produce a 14-MHz output. This stage is keyed via Q8 (see **fig. 2**). Harmonics and other unwanted products are removed by the bandpass filter at L3, L4. Broadband amplifier Q6 then boosts the filtered signal to drive FET driver stage Q7. This stage operates in class AB, and delivers about 0.7 watts at the output of a 50-ohm Pi-network. If desired, a simple class-C configuration using a bipolar device could be substituted without major disruption to the circuit board.

Q11 is a broadbanded class-C PA (see **fig. 3**) that delivers 12 to 15 watts output into 50 ohms. A five-section half-wave filter suppresses harmonics, and an adjustable diode detector provides a dc signal for metering rf output.

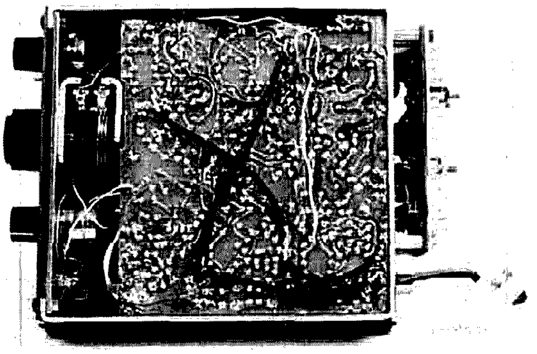
VFO Q4 tunes from 5.0 MHz to 5.1 MHz to cover the bottom 100 kHz of the band. Source-follower Q5 isolates the VFO and provides a low impedance drive to the mixers. BFO Q3 utilizes diode-switched capacitance in series with Y1 to provide a 700-Hz offset during transmit.

The CW control module provides three functions. Q8, the dc switch, simultaneously activates the transmit mixer, sidetone oscillator, and relay driver when the key is depressed. An RC input circuit shapes rise time, which in turn softens the CW wavefront and prevents key-clicks.[3] Twin-T oscillator Q9 generates a 700-Hz sidetone, which is fed to audio amplifier U4 during transmit.[4] Relays K1 and K2 are controlled by

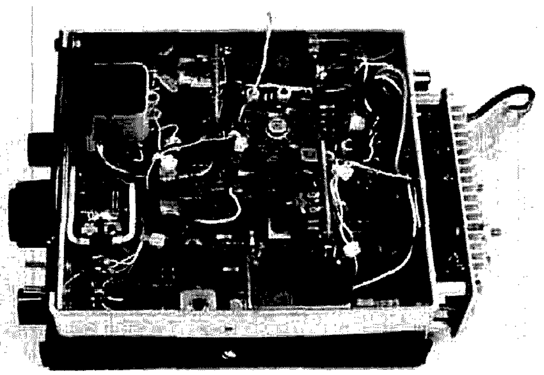
Rick Littlefield, K1BQT, Box 114, Barrington, New Hampshire 03825



The 20-meter sub-compact QRP transceiver has most of the features of a full-sized radio, yet occupies very little space.



Main board is mounted about 1/4 inch above the bottom of the frame to allow space for wires and parts mounted on the bottom of the board.



The CW control module and CW filter are mounted onto the main board with stiff buss wire. FL1 is epoxied to side panel. The power amplifier is mounted externally on the back panel to reduce heating of internal circuitry during transmit.

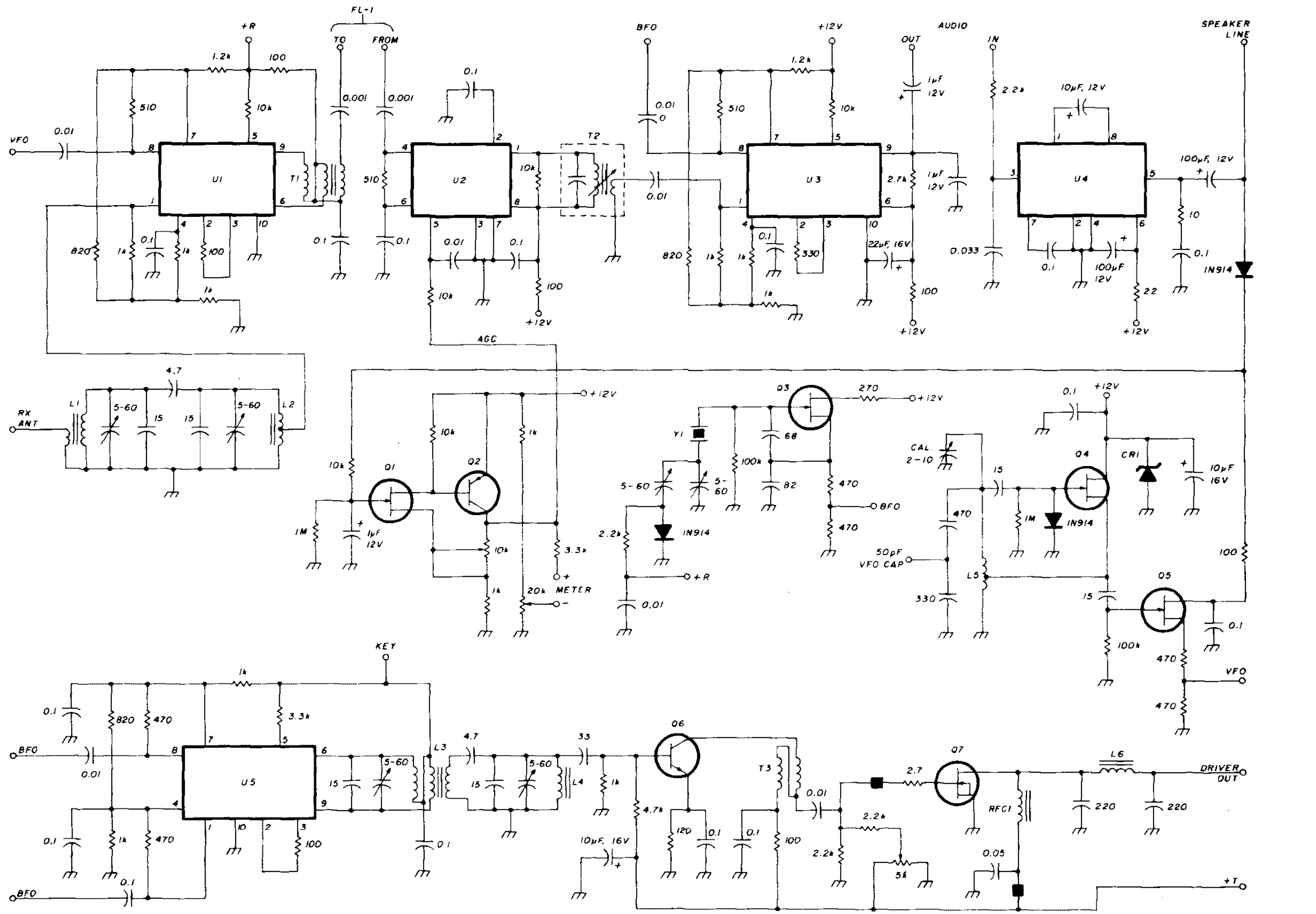


fig. 1. Main circuit diagram (see parts list, page 12).

Ferrite beads	*FB43-101*
FL1	*9-MHz crystal filter, Showa SF0922B or equivalent*
L1	*20 turns No. 26 on T37-2, 2-turn link*
L2	*20 turns No. 26 on T37-2; tap at 10 turns*
L3	*10 turns No. 28 trifilar wound on T37-2*
L4	*20 turns No. 26 on T37-2*
L5	*36 turns No. 32 on 1/4-inch form; tap at 9 turns, enclose in 1/2 x 1/2 x 3/4-inch shielded can*
L6	*12 turns No. 24 on T37-2, spread to occupy 80 percent of form length*
Q1, Q3, Q4, Q5	*MPF102*
Q2	*2N3906*
Q6	*2N2222A*
Q7	*DV-1201K (M/A-COM, 1742 Crenshaw Blvd., Torrance, CA 90501)*
T1	*10 turns No. 28 trifilar wound on FT37-43*
T2	*10.7 MHz output transformer, green core*
T3	*10 turns No. 26 bifilar wound on FT37-61*
U1, U3, U5	*MC1496G*
U2	*MC1350P*
U4	*LM386*
VFO capacitor	*50 pF, 6:1 reduction drive*
Y1	*8998.5-kHz crystal, series resonant*
Z1	*Zener, 9 volts @ 400 mA*

switching FET Q10. Delay time is set via an adjustable RC circuit on the gate of Q10.

CW filter U6 is a two-stage audio-bandpass CW filter (see **fig. 4**) built around a dual op-amp. This is a simplified version of a popular three-stage design.[5] With the values shown, center frequency was measured at 720 Hz. A response curve is shown in **fig. 5**.

Finally, U7 is a monolithic 12-volt regulator that protects and stabilizes voltage to all stages except the PA (see **fig. 6**). All T/R switching is handled by miniature DPDT relays K1 and K2. An extra set of contacts is available for switching an external amplifier.

construction

Space is limited, so choosing small components is important. All four boards were designed to accommodate 1/4-watt resistors, low-voltage ceramic or monolithic caps, tantalum dips, miniature vertical trimpots, and miniature trimmers. Attempting to substitute larger devices will quickly result in overcrowding.

Monolithic capacitors were used in most frequency-critical rf circuits. Silver mica or high quality NPO ceramic devices can be substituted in most cases, as

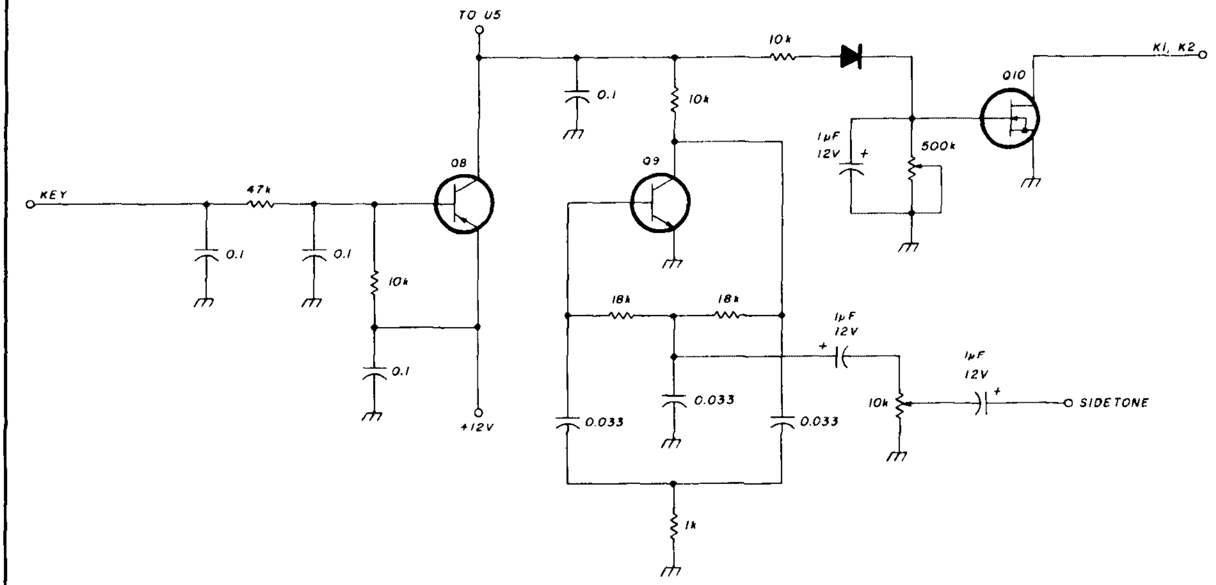


fig. 2. CW control module schematic.

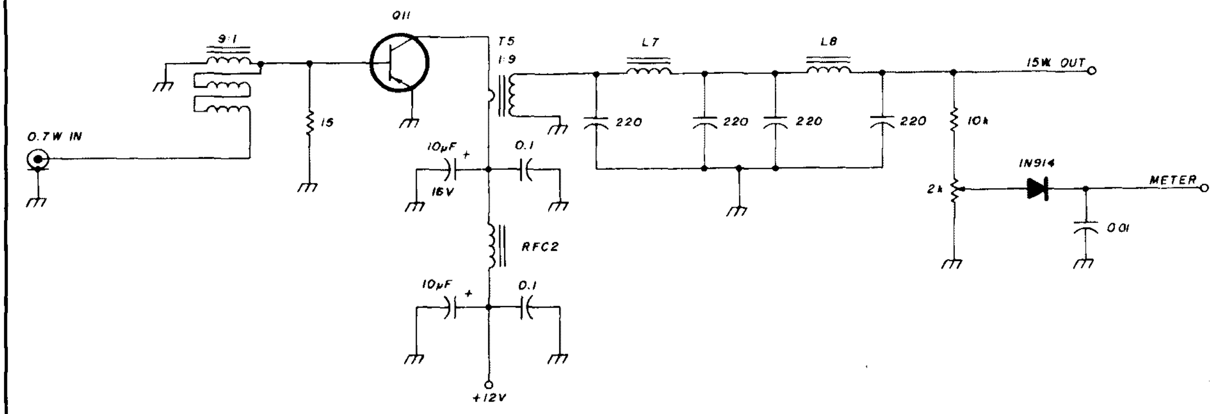


fig. 3. 15-watt class C power amplifier module schematic.

long as they're within 5 percent of specified values. While polystyrene capacitors are typically specified for frequency-critical elements in audio oscillators and active filters, monolithics are much smaller and seem to work just as well. To ensure accuracy, I matched active filter values carefully with a capacitance meter. Finally, I recommend using flexible small diameter wire and lavalier microphone cable for jumpers and interconnections. Harnessing leads together will reduce the chance of breakage. A complete kit and most of the individual parts are available from Radiokit.*

The parts layout for the main board is shown in **fig.**

7. It's generally easier to mount low-profile components (such as resistors, capacitors, and ICs) first, saving taller items (like trimpots and inductors) for last. FT-type toroid cores should be coated with clear nail polish before winding to prevent damage to enameled wire insulation. Toroids and chokes should be installed last and glued in place to prevent movement and lead breakage. When all parts and wires are installed on the top side, refer to **fig. 8** and complete the bottom side.

*For details, contact Radiokit, Box 973, Pelham, New Hampshire 03076.

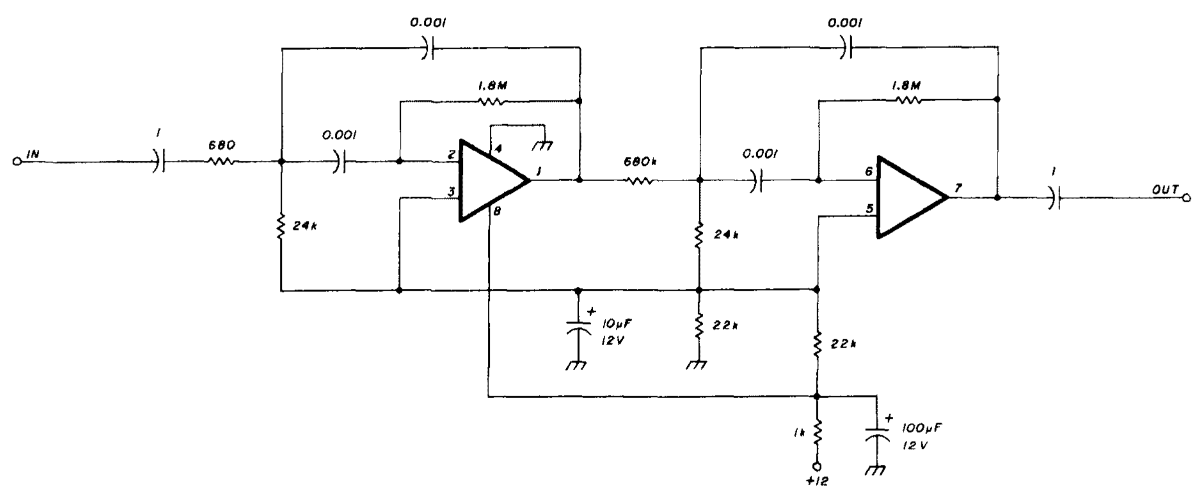


fig. 4. CW filter module schematic.

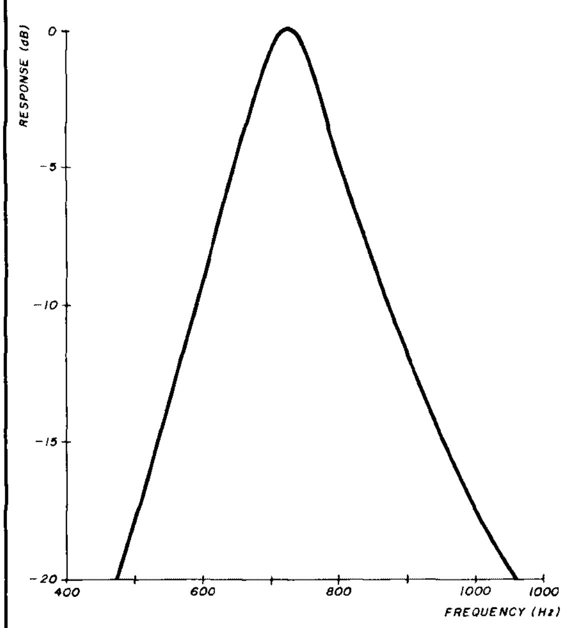


fig. 5. Measured frequency response of two-stage active audio CW filter. Filter significantly improves signal readability during crowded band conditions.

Construct the control module fig. 9, and the CW filter module fig. 10 in similar fashion. Solder all power and signal leads to the foil side of these boards.

The PA circuit board is mounted onto the PA heatsink before construction (foil side up). All components are mounted stripline-style by soldering them directly to the tracks (fig. 11). Note that a rectangular hole is cut in the board to accommodate mounting the PA transistor directly to the heatsink. Since the MRF479 is an emitter-tab device, no insulating washer is used between the tab and ground.[6]

packaging

I packaged my transceiver in an open frame cabinet similar to what many commercial equipment manufacturers use. Mounting tabs for the main board were made by tacking solder lugs onto the foil, then fastening them onto the frame with No. 4-40 screws. The CW control board and CW filter modules were mounted into the main board with stiff bus wires. Crystal filter FL1, relay K2, and the meter are held in position with contact cement. Voltage regulator U7 is fastened to the frame with No. 4-40 hardware. The PA is mounted to the outside of the back panel with 3/4-inch spacers. This approach keeps circuit board and chassis wiring very accessible, and reduces the box size to a bare minimum. However, packaging is tight, and a cabinet of this type requires a metal shop and a fair amount of care to construct.

Since layout isn't very critical, the transceiver can be constructed in any convenient case — as long as a few basics are taken into account to ensure VFO stability. I recommend keeping the PA module on the outside of the case to reduce interior temperature fluctuations during transmit. Also, make sure all external VFO components are securely mounted and connected with short, rigid leads. Finally, route interstage wiring well away from VFO components. Mounted in a Hammond cast aluminum case, with a portable VCR battery, this rig would make an extremely tough and self-contained communications package for rough-and-tumble DX enthusiasts!

Once the packaging is done, and all interconnec-

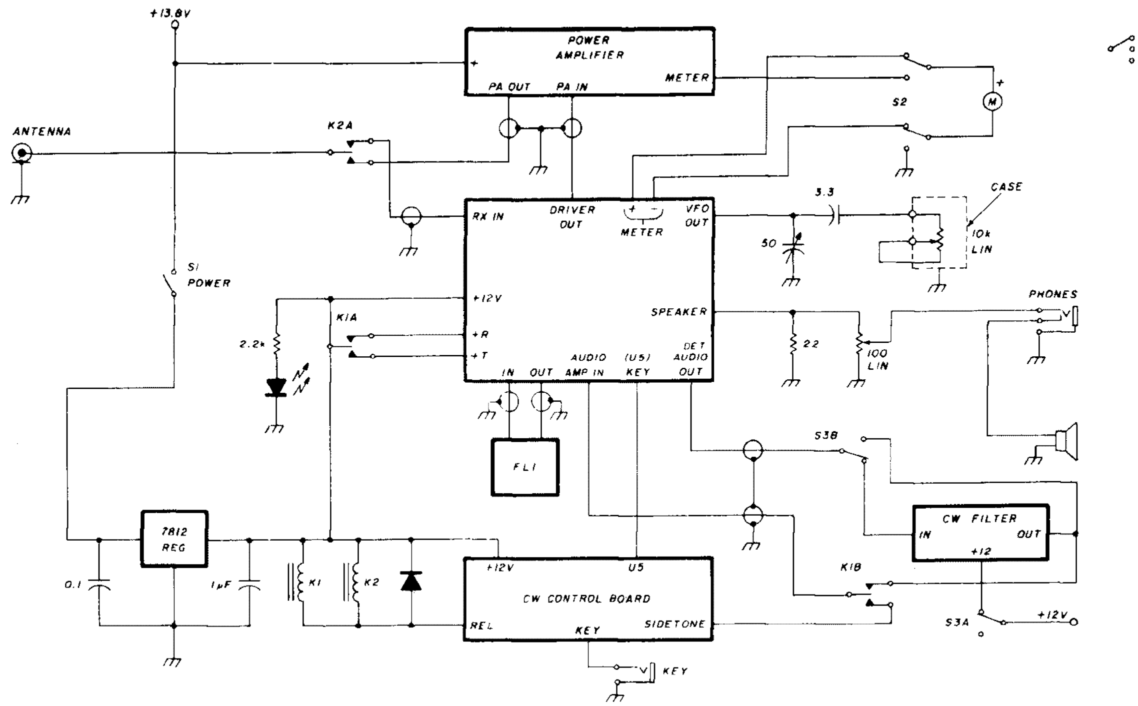


fig. 6. Module interconnections for completed transceiver. Note that K1 is actually located on the main board.

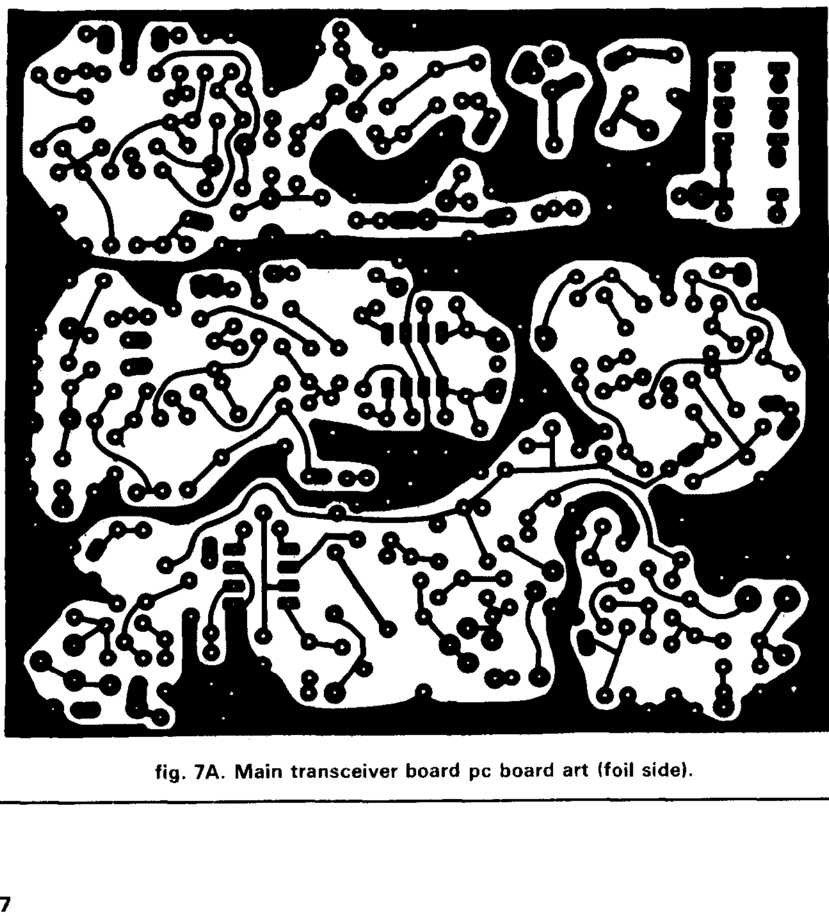


fig. 7A. Main transceiver board pc board art (foil side).

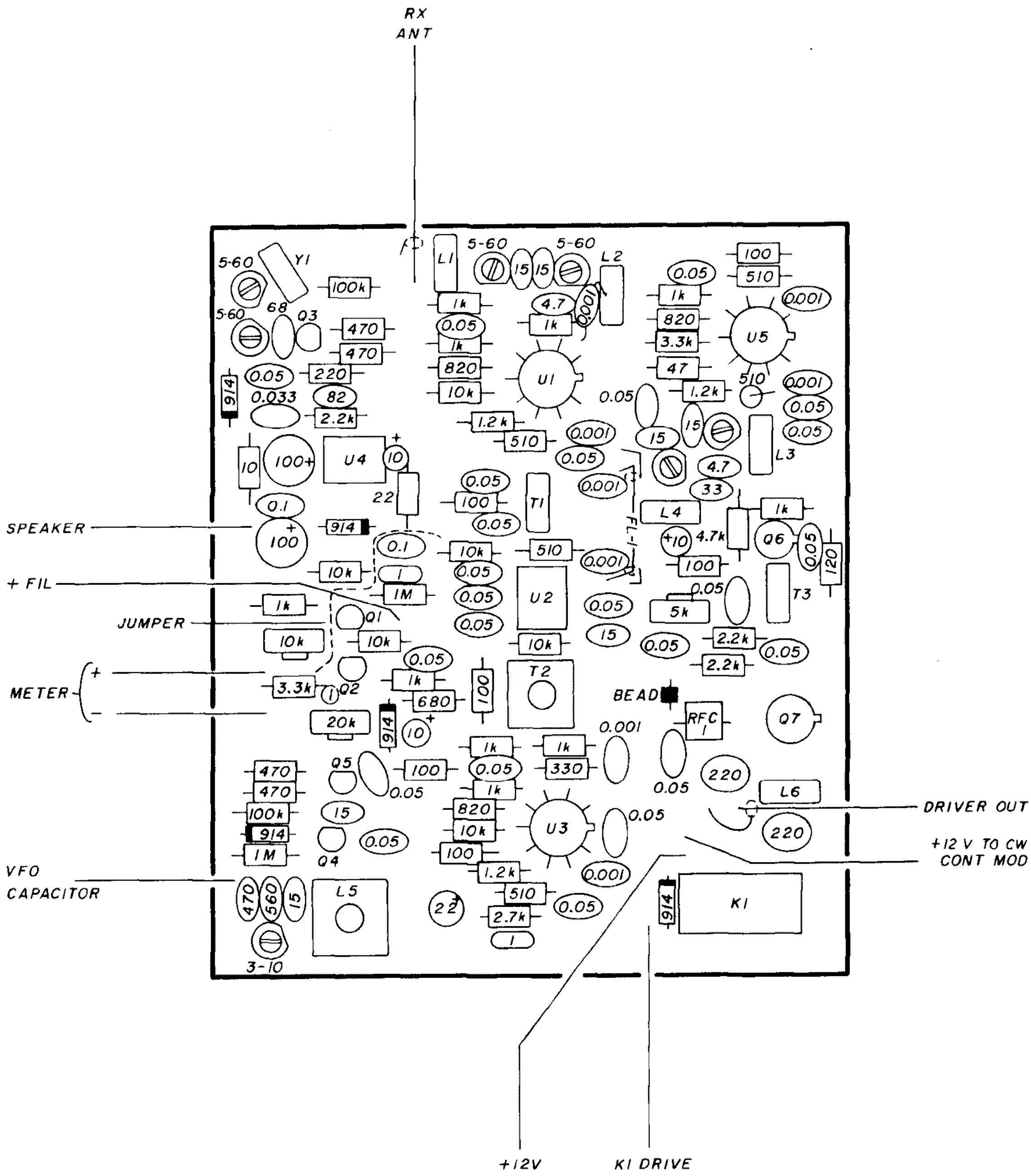


fig. 7B. Main transceiver board component layout.

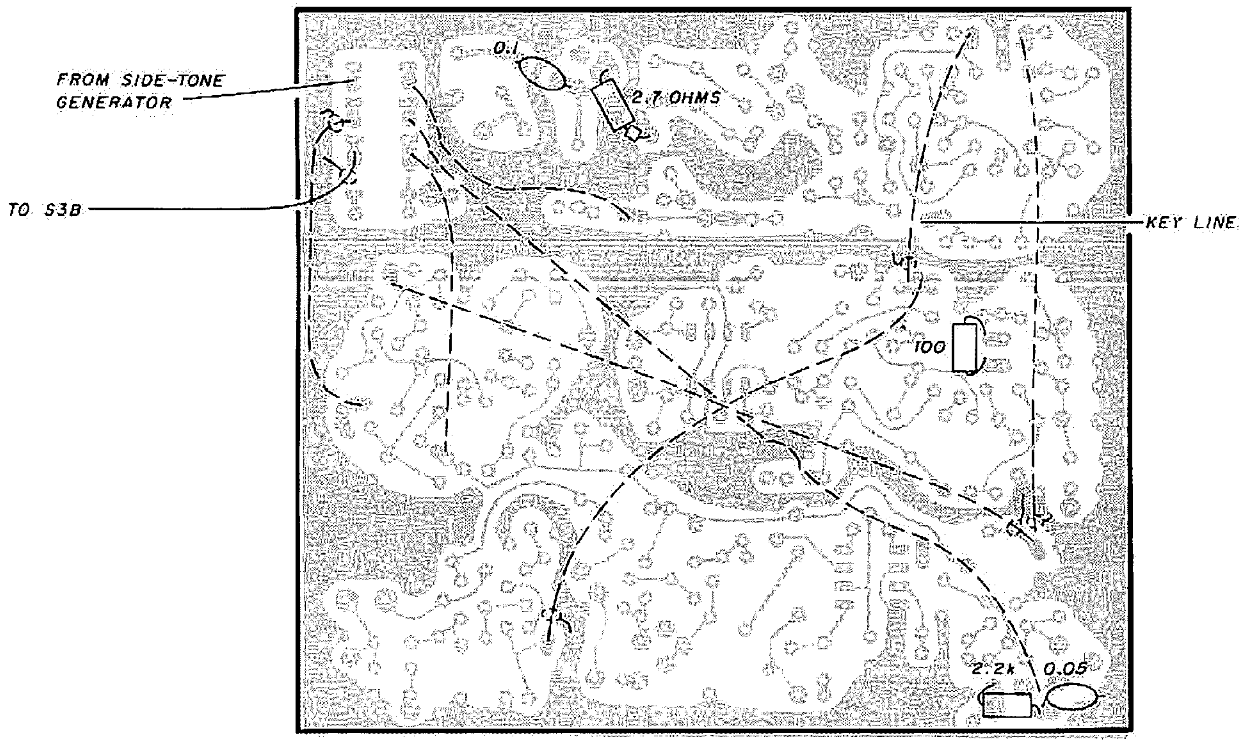


fig. 8. Wiring placement guide for main transceiver board.

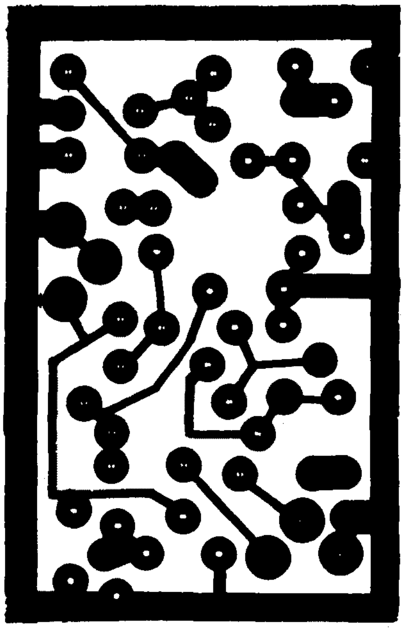


fig. 9A. CW control module pc board art (enlarged 2X).

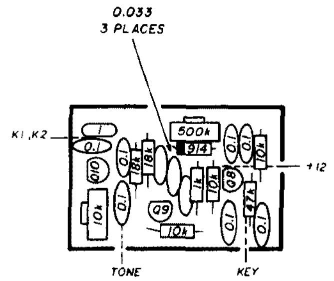


fig. 9B. CW control module component placement guide.

properly. Operation from a standard 12-volt battery may require regulating the main board at 10 volts with an adjustable device such as the LM317.

tune-up

The transceiver is easy to align (**fig. 12**). First, make sure both oscillators are functioning properly. Then monitor VFO output with a frequency counter or all-band receiver, and net VFO tuning into the 5.0 to 5.1 MHz range. Large adjustments may require substitut-

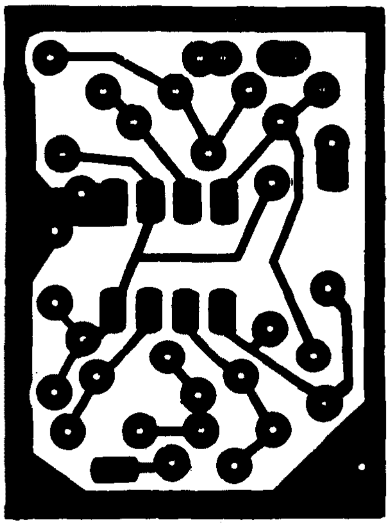


fig. 10A. CW audio filter pc board art (enlarged 2X).

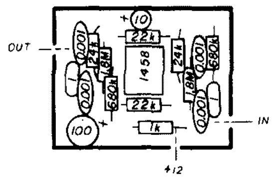


fig. 10B. CW audio filter component placement guide.

tions are made (**fig. 6**), it's time to double-check the wiring and connect a power supply. I use a compact 13.8-volt supply that's capable of supplying 2.5 amps for intermittent periods. Although this supply is regulated, I added 2000 μF to the output circuit to help the regulator track the current surge as the transmitter is keyed. Note that the transceiver's voltage regulator needs a supply voltage of at least 13 volts to function

ing fixed-value capacitors (the VFO calibration trimmer has a range of about 50 kHz). Once the VFO tunes properly, the dial can be calibrated.

Next, monitor BFO output and set up BFO trimmers. When correctly adjusted, frequency on receive will be 8998.5 kHz (with +12 volts applied to the switching diode), and 8999.2 kHz on transmit (voltage removed from the switching diode). This provides a standard 700-Hz transmit offset. Since the two trimmers interact, some retuning will be necessary.

To set up the receiver section, first adjust AGC bias to 5 volts as measured at test point No. 1; then zero the S-meter. Tune T2 for maximum background noise in the speaker. Finally, peak both receiver bandpass filter trimmers for maximum sensitivity at 14.050 MHz (make sure there are two signal peaks per revolution).

Next, connect a power meter and dummy load to the transceiver output. To set a sidetone level, depress

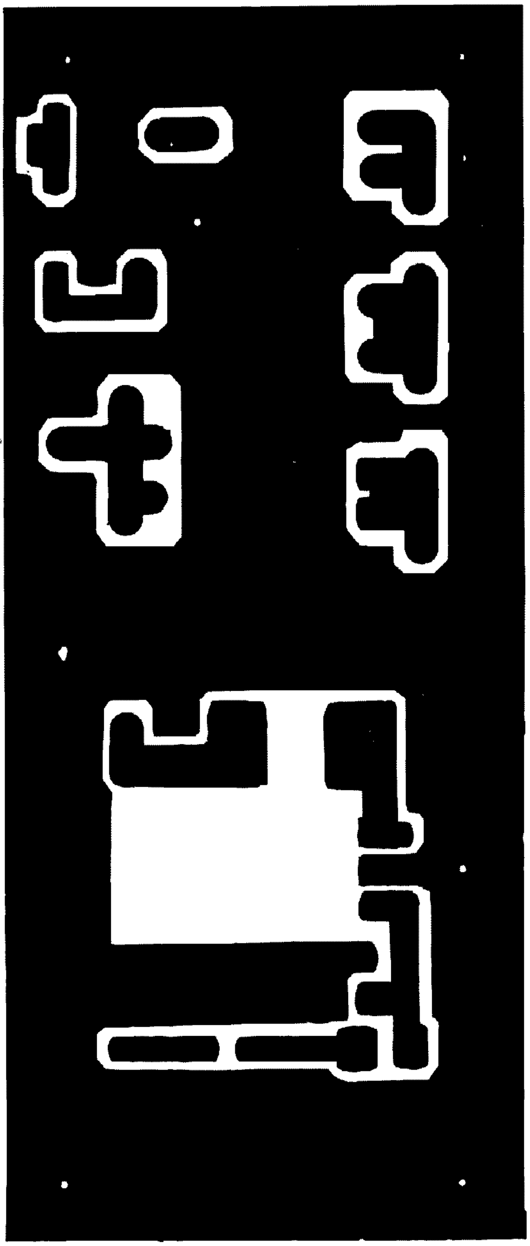


fig. 11A. 15-watt PA pc board art (enlarged 2x).

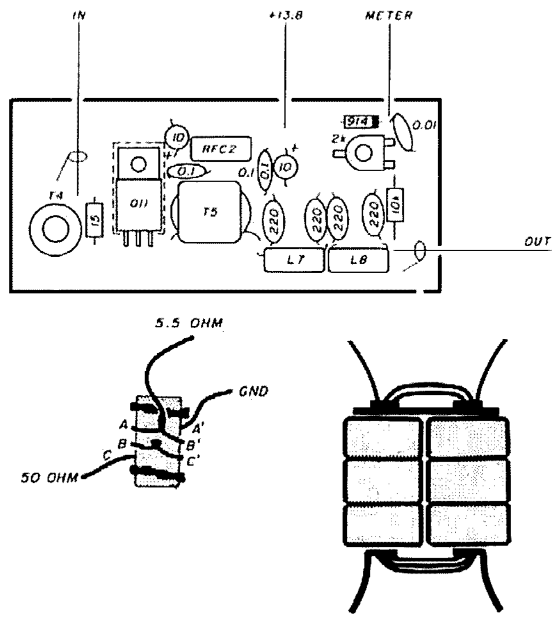


fig. 11B. 15-watt PA component placement guide.

the key and adjust the sidetone trimmer for a reading of S9 on the S-meter. Then key the transmitter and peak transmit bandpass filter trimmers for maximum output. Use a nonmetallic tuning tool; one trimmer is part of a balanced circuit, and will be detuned by a metallic blade. Finally, key the transmitter and set the bias of driver Q7 to 3 volts. Measure bias voltage at test point No. 2 with a high-impedance voltmeter.

The PA is broadbanded and requires no tuning. With a supply voltage of 13.8 volts, the indicated output should be between 12 and 15 watts into a 50-ohm load. Set the rf meter's sensitivity by adjusting the 2-k rf meter trimmer on the PA board for a 3/4-scale reading. The semi-break-in delay trimmer can now be adjusted to suit sending speed and operating style.

All that remains is to connect an antenna and try your luck. Antenna SWR should normally be held below 2:1 with solid-state rigs, and this one's no exception. However, momentary accidents do happen, and my MRF479 PA has survived several with no damage. The rf meter can help you avoid trouble; it will read excessively high or low when a serious mismatch is present.

conclusion

As I called my first CQ, I wondered if 15 watts into a dipole would cut the mustard. After all, 20 is a popular band, and finding a clear spot to operate can be difficult. My fears were quickly dispelled when a UQ2 came back and gave me a 579. Several more DX contacts followed — all with good reports. I quickly discovered that 15 watts was enough power to work almost anything I could hear, including ZLs and VKs. That reliability, along with "extras" like the CW filter, a smooth sidetone note, and semi-break-in, make this rig fun to operate. Now, all I *really* need is the proper test platform from which to field-test the transceiver's portable capability. A large schooner — something with two masts headed for a tropical island — would be just right!

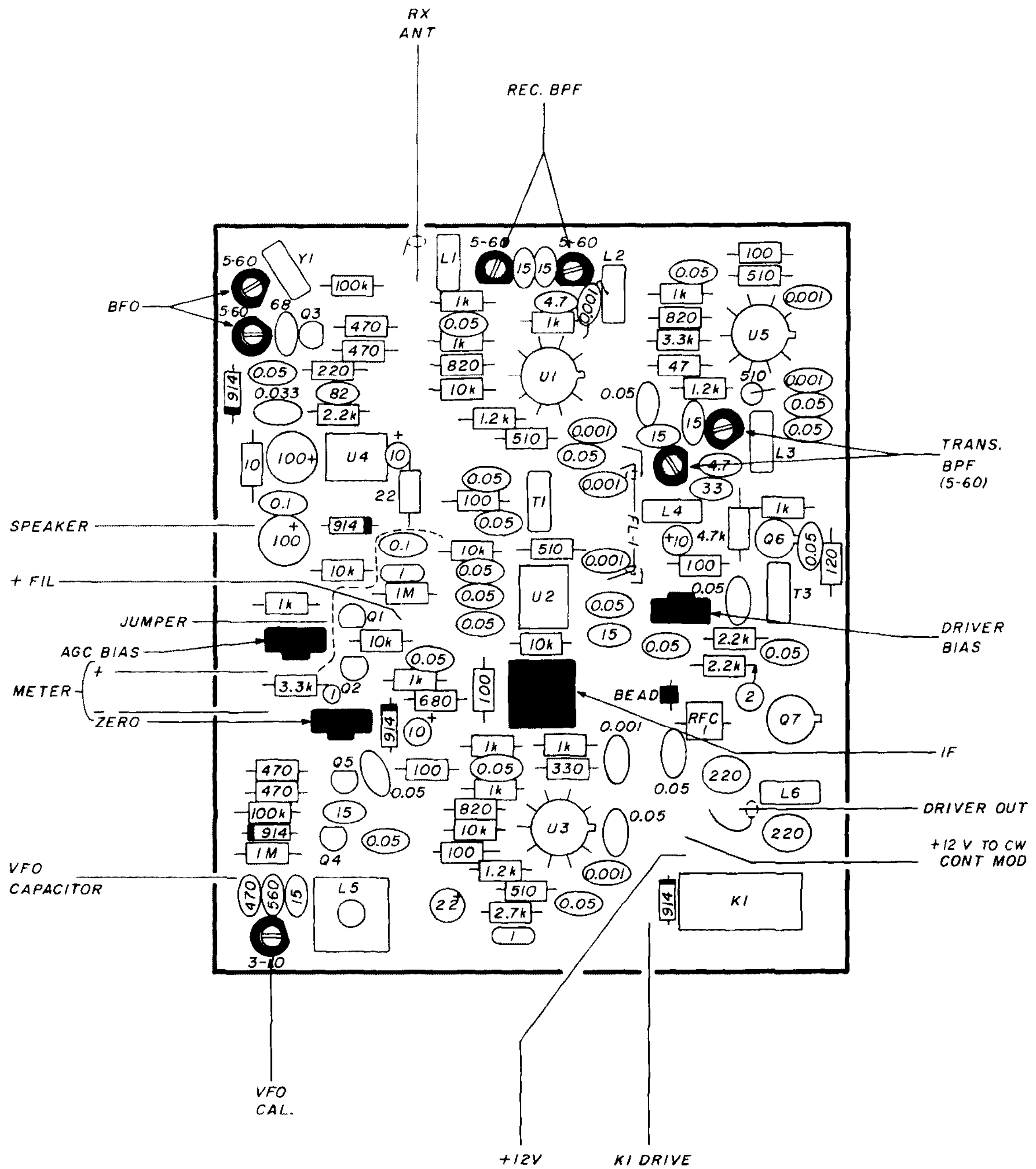


fig. 12A. Alignment control locations, main transceiver board.

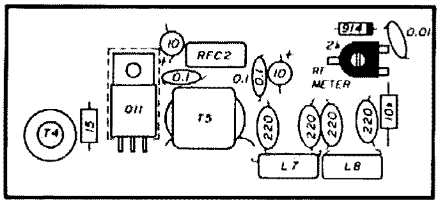


fig. 12B. Alignment control locations, power amplifier board.

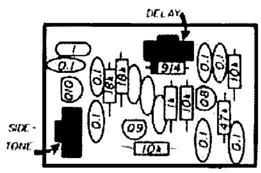


fig. 12C. Alignment control locations, CW control module.

references

1. Rick Littlefield, K1BQT, "Compact SSB Receiver," *ham radio*, November, 1983, page 10.
2. Rick Littlefield, K1BQT, "A Compact 75-Meter Monoband Transceiver." *ham radio*, November, 1985, page 13.
3. Doug DeMaw, W1FB, "The Principles and Building of SSB Gear," *QST*, January, 1986, page 15.
4. James Forkin, WA3TFS, "Extending the Modular Two-Band Receiver," *ham radio*, November, 1984, page 57.
5. Doug DeMaw, W1FB, "Beating Rotten QRM – CW Filtering for the Beginner," *QST*, October, 1981, page 38.
6. Staff, Technical Information Center, *Motorola RF Data Manual*, 3rd Edition, Phoenix, Arizona, 1983.

bibliography

The Radio Amateur's Handbook, G. Woodward, W1RN, Editor, 62nd Edition, ARRL, Newington, Connecticut, 1985.
Solid-State Design for the Radio Amateur, Wes Hayward, W7ZOI, and Doug DeMaw, W1FB, ARRL, Newington, Connecticut, 1985.

ham radio

short circuit

Figure 5(E), omitted from W1JR's "VHF/UHF World" in the May issue (page 92), appears below:

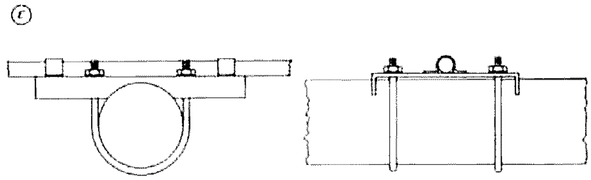


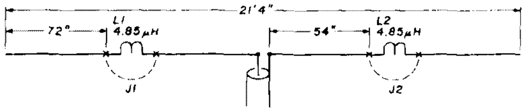
fig. 5(E). This non-piercing above-the-boom mounting method, devised with the help of Don Cook, K1DPP, is recommended for homebrewed antennas.

compact travel antenna

Complete the installation — add this antenna to your compact rig

Traveling with a portable rig* is fun, but raising a temporary antenna can be difficult. For one thing, few resort managers are willing to lend their flagpoles and trees to unsightly wires that could garrote paying customers. And, of course, there's always the possibility of a mishap — a poorly thrown beanbag dimpling the roof of a vintage Mercedes, for example. These liabilities are *real*, and all too often I've settled for makeshift alternatives to avoid an unpleasant confrontation.

Thinking there must be a better way, I set out to build an antenna that would provide solid on-the-road performance without scaring the spirit of cooperation out of resort owners. I started by writing down my needs: it must be self-supporting, easy to mount, and collapsible; it must cover 14-30 MHz, perform with high efficiency in either vertical or horizontal polarization, be made from available materials, and require no external matching devices.



Loading coils:
L1,L2 24 turns 3/4-inch x 16 TPI coil stock (B&W No. 3011 or Air Dux 616T) or 14 turns 1-1/2 inch x 8 TPI coil stock (B&W No. 3018 or Air Dux No. 1008).
J1,J2 8-inch clip leads.

fig. 1. Overall length of antenna is 21 feet, 4 inches, about 66 percent of a full-sized dipole. Two 4.85 μH inductors are required to resonate it at 14.05 MHz. Jumpers bypass inductors for 21-30 MHz operation.

Remembering my old Cushcraft "Trick-Stick" VHF dipole, and how easy it was to set up and use, I reasoned that a loaded hf dipole of similar size might be the answer.

design

Since I didn't want a high-budget project, my first step was to raid my junk pile, where I found several 4-1/2 foot lengths of 3/8-inch diameter thick-wall aluminum tubing. I decided that these would make sturdy center sections.

Six-foot collapsible replacement antennas from Radio Shack would be perfect for the ends. This would give me a 21-foot element in four pieces (**fig. 1**). Since 21 feet is a healthy 66 percent of full size, I concluded that my antenna would be efficient, and provide a good match without need for special matching devices.

loading coils

Power handling wasn't a concern, since my portable rig runs 15 watts. But efficiency was very important. With QRP and marginal locations, every watt counts! A friend who designs antennas for a living cautioned me against close-winding loading coils with enameled wire. His experience indicated that high-*Q* air-wound stock is less lossy, and well worth the extra investment. He said I might get away with using 3/4-inch 16 TPI (turns per inch) miniductor for low power, but strongly recommended larger diameter stock with 8 or 10 TPI spacing.

construction (see table 1)

Since this antenna is intended for temporary use,

Rick Littlefield, K1BQT, Box 114, Barrington, New Hampshire 03825

*See K1BQT's "A Compact 20-meter CW Transceiver" on page 8 of this issue.

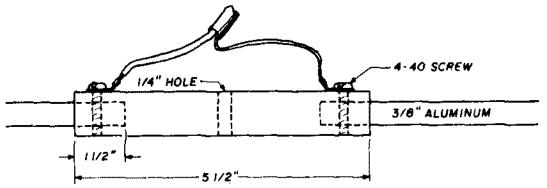


fig. 2. The 3/8-inch elements slip into the center block, and lock in place with No. 4-40 screws. Only one element need be removed to break down and transport the antenna.

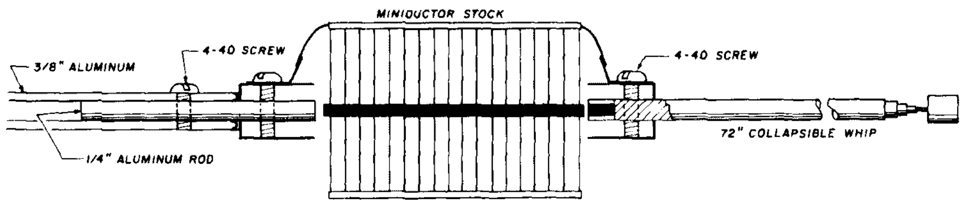


fig. 3. End sections slip into 3/8-inch elements and are locked in place with a No. 4-40 screw. Solder lugs provide electrical connections for loading coils.

I concentrated on making it lightweight and easy to assemble in the field. The center block was made from a piece of 5-1/2 inch x 3/4-inch plastic rod stock (see **fig. 2**). This material is fairly inexpensive, easy to machine, and available from most plastic supply houses. Each end was drilled to a depth of about 1-1/2 inches to accept the 3/8-inch tubing. The block and tubing sections were drilled and tapped to accept a No. 4-40 screw, which locks each element in place. This screw also provides electrical connection for the feedline. The center of the block can then be drilled to accept any kind of mounting scheme, including the one shown here or a standard TV mast U-bolt.

The loading coil and collapsible whip are constructed as a single assembly (see **fig. 3**). The coil support is a 3-inch length of 1/2-inch diameter plastic rod. A 1/4-inch solid aluminum stub is installed in one end to mate with the 3/8-inch element tubing. The whip is inserted in the other end. Note the location of the solid insert at the base of the whip. The locking hole must be drilled through this insert to ensure a secure mount and good electrical contact. Install solder lugs on mounting hardware; these will be needed for connecting the loading coils. If you plan to operate in foul weather, protect the coils with a plastic sleeve. Without them, rain and snow may detune the antenna and make it temporarily unusable.

To simplify feedline attachment, I hard-wired an electrical half wavelength (22 feet) of RG-58U directly to the center block. This accommodates most out-the-window and off-the-balcony setups. Since this antenna is certain to be installed in imperfect locations, it may be especially beneficial to decouple the feedline from the antenna. While a balun can be installed for this purpose, looping five or six tight turns in the feedline or slipping a few large ferrite beads over the cable jacket will prove just as effective.

Feel free to modify the design to suit your own particular needs. I've constructed a second version of the antenna that breaks down into 2-1/2 foot sections — just for air travel. A friend of mine built a ruggedized model for permanent installation on his TV mast. In reality, moving loading coils closer to the ends, adjusting element lengths, and using different tubing schemes will probably do little to change performance. The most critical factors are keeping the length greater than 20 feet and using high-*Q* loading coils to achieve resonance. A grid dip meter works fine for making initial adjustments.

Table 1. List of materials for compact antenna.

2	3/8-inch OD x 53-inch aluminum tubing
2	1/4 x 3-inch aluminum rod
1	3/4 x 3-1/2 inch aluminum channel stock
1	3/4 x 5-1/2 inch plastic rod
2	1/2 x 3-inch plastic rod
2	Radio Shack 72-inch collapsible antenna (No. 270-1408).

supports

To support my antenna, I cut a 6-foot strip of 3/4 x 1-inch poplar. Wood is preferable to metal in this application because it's strong, light, and less likely to damage or discolor woodwork. A short piece of 3/4-inch aluminum channel stock was used to square the center block so it would lock securely into a square notch cut into the mast. A single 1/4-inch bolt holds the antenna in place (see **fig. 4**).

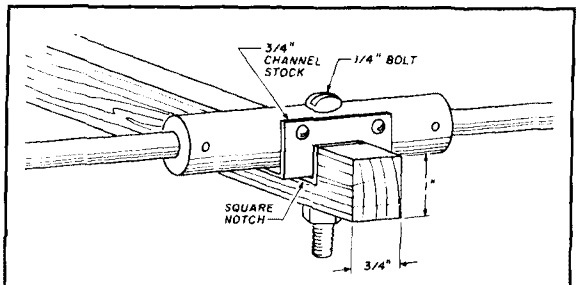


fig. 4. A short piece of square channel stock locks center block firmly in place on support mast. A 1/4-inch bolt holds the antenna in place.

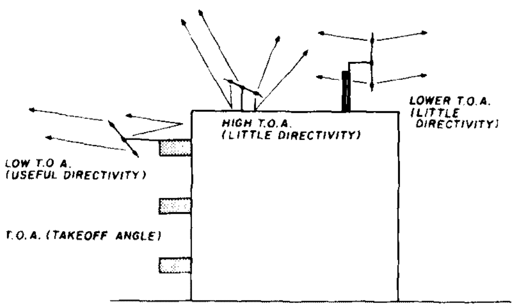


fig. 5. Conductive surfaces on buildings may be an advantage or disadvantage, depending on how you use them. On 20 meters, placing a horizontal dipole near the surface of a conductive roof may produce poorer results than mounting vertically, or mounting off to one side of the building!

When setting up the antenna, almost anything can be a potential supporting structure (window sills, balcony rails, fire escapes, standpipes, and existing TV masts are all favorites). Attaching antenna and mast to one of these supports can be a real exercise in "jerry-rig" engineering. Having the right tools helps! Gaffer's tape, lightweight ratcheting C-clamps (Stanley 83-157 or equivalent) and motorcycle bungie cords are essential tools of the trade for the imaginative field-installer!

performance

For initial testing, I mounted the antenna out a second story window, about 5-1/2 feet from the side of the building. Sections went together without difficulty, and the completed assembly seemed well balanced and easy to handle. The support mast was clamped to the window casement with a C-clamp.

After pruning the loading coils for resonance at

14.05 MHz, I measured a minimum SWR of 1.4:1. My noise bridge read the impedence as 38 ohms — an acceptable load for broadbanded solid-state rigs. Listening across the band, I was encouraged to hear several 599+ signals. Running 15 watts, I called two lengthy CQs, both yielding no reply. Beginning to think the worst, I tried again. This time, a much-welcomed CT3 came back with a 569 report. Several more DX and stateside contacts followed, with signal ranging from 559 to 589. Flipping the antenna to vertical polarization brought similar results.

other bands

Although untested on the other bands, this antenna should do very well on 18, 21, 24, and 30 MHz. For 18-MHz operation, simply readjust the collapsible end sections for minimum SWR. For 21 MHz and up, place 8-inch jumper wires across each loading coil (the extra jumper length is needed to make the antenna resonate at 21.0 MHz). Collapsing the length of the end sections (with jumpers in place) will provide continuous coverage through 10 meters.

site suggestions

Here are some tips to help you achieve maximum performance:

- **Look for a high, open location.** Get above the roofline if you can, but keep directivity and takeoff angle in mind (**fig. 5**).
- **Keep the antenna at least 5 or 6 feet from the building surface.** Proximity to electrical wiring, foil insulation, and structural metal can detune it. Bending elements outward may help to decouple the ends from a metal structure.
- **When you side-mount to a building, try to locate the antenna on the side facing the desired direction of transmission.** Better to use the structure as a reflector than as a shield!
- **If there are horizontal wires close by, vertical polarization may work better.** When using vertical polarization, make sure the bottom leg is at least 6 feet above ground. Also, make sure the antenna is clear of people and pets. Even QRP rigs can develop enough rf potential at element tips to cause painful burns and injury.

conclusion

Whether you're jet-setting to VP2-land, driving cross-country, or working tabletop DX from the local flea market, a good portable antenna will help you get on the air with a minimum of hassle and frustration. I am continually pleased with how well this one has worked for me. On occasion, it has even been spotted emerging from my office window . . . at lunchtime, of course!

ham radio

ham radio TECHNIQUES

Bill Orr, W6SAI

time and frequency station WWVS

I couldn't resist the temptation. Driving along the south coast of Kauai Island, Hawaii, I saw a sign reading *U.S. Department of Commerce, National Bureau of Standards Radio Station WWVH.* In a microsecond, I turned off the highway and headed toward a brace of interesting looking antennas. After passing through a checkpoint, I quickly arrived at WWVH and was greeted by Ernie Farrow, the Engineer-in-Charge.

What an interesting visit! A low-frequency DXer would have been visibly shaken by the sight of the extensive vertical antenna and ground screen for the 2.5-MHz transmissions of WWVH. The antenna would be a "bomb" on 160 meters!

Ernie surprised me when he mentioned the time and frequency transmissions from WWVS, a station I never knew existed. WWVS, it seems, refers to the satellite-disseminated time code using the GOES (Geostationary Operational Environmental Satellite) satellites of NOAA (National Oceanic and Atmospheric Administration). The time code can be used for general-purpose reference time in the Western Hemisphere from two satellites on a nearly full-time basis.

The two active GOES satellites are in orbit over the Pacific. The satellite that serves the western United States, Canada, and western South America operates at 468.825 MHz and is located at 135 degrees West Longitude. The eastern satellite can be received on 468.8375 MHz and is positioned at 75 degrees West Longitude to serve the eastern seaboard of the United States, as well as Brazil and western Africa.

The time code to the satellites is sent from Wallops Island, Virginia. Because the path delay to and from the satellite is about 260,000 microseconds, the signals are advanced in time by this amount. The arrival time of the signal back on earth is corrected to within 16 microseconds. Other path delays are known, and the exact satellite position is included in the downlink signal for correction by the observer.

Additional information on the transmissions via WWVS and general data on time signals can be obtained in *NBS Special Publication 432*, available from Time and Frequency Division, National Bureau of Standards, Boulder, Colorado 80303.

Many thanks to Ernie Farrow at WWVH for an interesting tour, which is recommended to all visitors to the south coast of Kauai Island. Aloha, Ernie, and Mahalo!

(Note: Want to participate in the NBS 1987 survey? A brief explanation and a tear-out, postage-paid survey form follow this article. — Ed.)

nothing new under the sun!

Sam Pavone, W2DDN, sent me a copy of the original patent on the top-loaded vertical antenna, in common use today as a broadcast antenna and also as a DX antenna on the low frequency ham bands (see **fig. 1**). Looks familiar, doesn't it? Even the current distribution curve (marked "3") is what one would expect from an antenna of this type.

The U.S. Patent No. 930,746, however, was granted to Simon Eisenstein of Kiev, Russia on August 10, 1909! The preamble of the patent refers to Simon as "a subject of the Czar of Russia, residing in Kiew [sic], in said Empire of Russia." The patent then goes on to define the current in the antenna in terms of degrees and discusses the problem of corona discharge. In spite of the fact that the patent was witnessed by a lady with the unlikely name of Fannie Fisk, it is apparent that Simon knew his onions. I wonder what happened to him? *Did he disappear* from the pages of history after filing this contribution to radio communication?

the W0SVM minibeam design

Jack Sobel, W0SVM, has been working for some months on a minature beam antenna for hams who have restricted air space. His basic design consists of out-of-phase, loaded dipoles in the familiar W8JK configuration (**fig. 2**). Jack's first design is for a 40-meter beam with 7.5-foot spacing. Element lengths are about 37 feet. This is about half the size of a conventional 40-meter, 2-element beam. The experimental antenna uses No. 12 AWG copper wire for the elements and is hung between two supports. Eight-foot spreaders made of wood or PVC pipe are used for the test antenna.

The radiation resistance of the antenna seems to be about 5 ohms, so its operational bandwidth is small. Jack feeds the antenna with a 50-ohm coax line and uses a Transmatch at the station to permit operation over a

reasonable portion of the 40-meter band. The phasing line between the elements is coiled up on the boom, or spreader. Jack hopes to get his antenna up high in the air so he can run some real operational tests. Perhaps with the coming of spring, he'll get some on-the-air tests with this interesting, compact antenna.

Jack has also built a compact beam of this design for 21-MHz operation. Spacing is less than 6 feet and overall element length is about 12 feet. For the elements, he uses 3/4-inch diameter copper pipe, available from plumbing supply stores in 10-foot lengths.

By changing the length of the phasing line, the beam pattern can be made unidirectional. As shown in the illustrations, both beams have a figure-8, bidirectional pattern, as is common with the W8JK antenna design.

Jack is experiencing lobe-splitting with the antenna and it remains to be seen if the simple feed system is distorting the antenna pattern. This problem won't be solved until milder weather comes to Missouri. Stay tuned for the latest developments.

more on "white noise"

My January column discussing the problem of "white noise" in the modern frequency-synthesized ham gear drew a lot of interesting mail. Obviously, I'm not the only one who has noticed this problem. Synthesizer noise is well known in the industry. Standards of measurement have been developed and most modern military and commercial communication equipment has limitations on this type of annoying radiation.

An interesting letter from Tom Bay, OZ5KG, outlines the ongoing problem he and other European Amateurs have had with a BBC (British Broadcasting Corporation) transmitter operating in the early morning hours on 7120 kHz. Tom provided the BBC with spectrum photographs showing the sideband noise, as monitored in Denmark.

While the problem has not been solved, the transmitter is now shifted to another frequency outside the 40-meter Amateur band, so the gener-

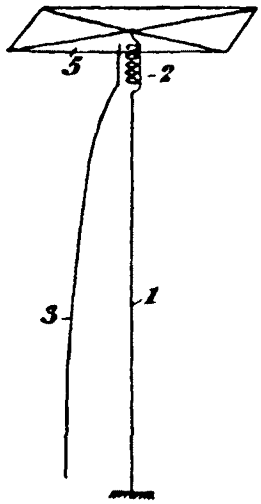


fig. 1. Patent application of August 10, 1909 shows original drawing of top-loaded vertical antenna.

ated noise doesn't affect the Danish Amateurs. This spring the BBC will again resume transmissions on 7120 kHz; it will be interesting to see if the wideband noise is still present on the signal.

phase noise standard?

Another letter came from John Grebenkemper, KA3LBO, of Saratoga, California. John said, in part, that the problem of excessive phase noise in phase-locked oscillators (PLO) isn't inherently due to the phase-locking of the oscillator. According to John, it's attributable, rather, to the necessity of keeping manufacturing costs under control.

John wrote, *In pre-PLL days, the oscillator would be designed with good coils and good capacitors in order to achieve temperature stability. This also resulted in a design which had a very high-Q oscillator resonant circuit. The high Q means that the oscillator is very good at filtering out the phase noise far away from the carrier. However, the newer designs that have PLOs can use much cheaper components because the phase-lock circuitry can now*

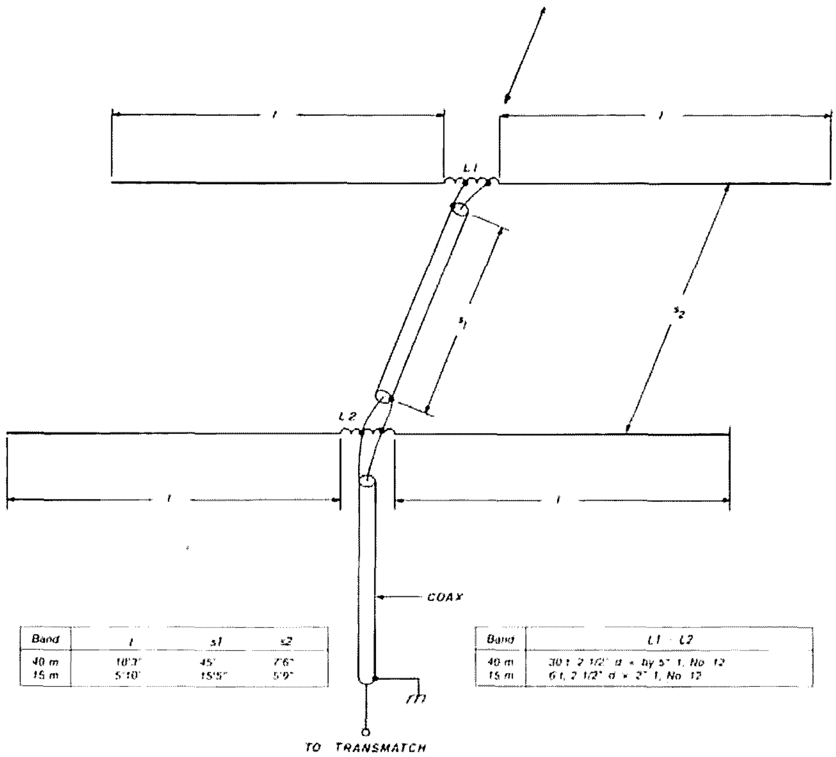


fig. 2. The experimental mini-W8JK beam of W0SVM. Elements lie in the horizontal plane. The center of the middle section of coax attaches to the center of coil L2, while this cable's shield is tapped nine turns from center. Connections are reversed at L1. The middle section of coax is wrapped into a coil and taped to the boom.

remove the local oscillator drift. Therefore, the manufacturer uses less expensive coils and capacitors and gets an oscillator which has a much lower Q and higher phase noise. The fact that the oscillator is phase-locked does not prevent the generation of noise that is far removed from the carrier.

I would suggest that Amateurs generate a set of standards for local oscillator phase noise. These standards would be much less stringent than some of the numbers that you mention. They only need to be adequate to guarantee non-interference based upon a reasonable set of assumptions. I would suggest something on the order of − 140 dBc/Hz at whatever offset frequency one desires to achieve no interference. This would guarantee no interference for a 1-kW effective isotropic radiated power transmitter at a distance of 1 mile. A number of Amateur transceivers could then be tested as to how well they meet these standards.

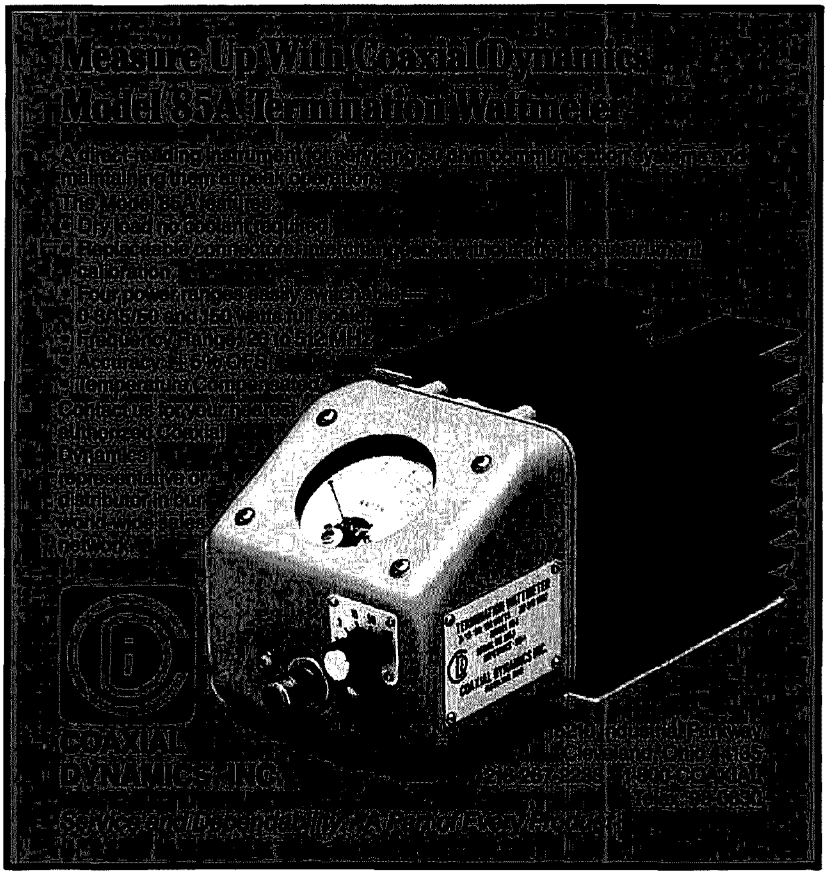
I have made phase noise measurements on an ICOM 745. It has a phase noise of better than − 120 dBc/Hz at a 10-kHz offset, and better than − 125/Hz at a 100-kHz offset. I think that is a pretty clean transceiver.

John closes his letter by saying: *Phase noise is really in the same state as receiver dynamic range was 10 to 15 years ago. It yet has to be addressed by specific articles which deal with its causes, effects, and how to measure it.*

I wish to thank the following individuals who sent me comments on white noise and also provided some interesting material on this subject:

- **Dr. William J. Robertson, W8KHO**, who sent a reprint of his article, "The Effects of Transmitter

*A more realistic value might be − 125 dBc/Hz at 10 kHz offset. — W6SAI



Noise and Receiver Local Oscillator Noise in a Co-site Environment";

- **Douglas R. Schmieskors, Jr., WA6DYW**, who sent a reprint of "Phase Noise Intermodulation and Dynamic Range," written by Peter Chadwick of Plessey Semiconductors, Swindon, England;
- **Chod Harris, VP2ML**, who sent copies of the "DX Bulletin," which summarized problems various Amateurs have had with white noise;
- **Art Block, W3YK**, who reported severe white noise on his synthesized transceiver when subjected to heavy off-channel interference;
- **Hal Jones, W6ZVV**, who sent a reprint of "Oscillator with Odd-symmetrical Characteristics Eliminates Low Frequency Noise Sidebands," from the *IEEE Transactions on Circuits and Systems*, September, 1984.

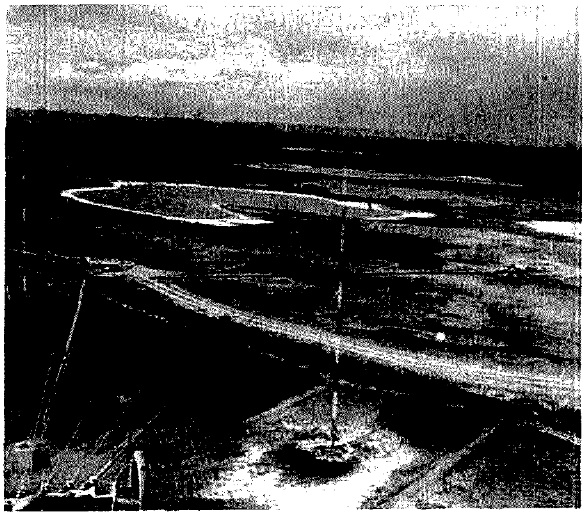
More information on the subject is coming in. Stay tuned.

ham radio

NBS time and frequency survey

Uncle Sam wants *your* input

The National Bureau of Standards has invited readers tc participate in its 1987 survey of users of NBS time and frequency services. More than 10,000 responses to the last survey (1975) were received; according to the NBS, these were "invaluable" in planning and carrying out the mission of the NBS over the past decade.



WWV and WWVB signals are broadcast from these antennas located about 7 miles north of Fort Collins, Colorado. The tall WWVB (60-kHz) array is fed from the building at left center, and the WWV antennas are powered from the building at right center. (Most of the WWV vertical dipoles are to the right, and scarcely visible.) Traces of the buried ground plane wires radiate from under the WWVB array.

This year the NBS is expanding the scope of its survey to include not only WWV, WWVH, and their associated telephone-accessible time-of-day services, but also the WWVB 60-kHz service and the newer GOES satellite time code broadcasts. Your responses will help NBS provide the best mix and levels of time and frequency services in the future, consistent with your needs and NBS resources.

Please answer each question that is appropriate to your use of the NBS services. Even if you answer only some of the questions, your responses will be of great help to NBS. If your responses represent the views of an entire organizational unit, please indicate that fact, clearly identifying the name of the organization you represent.

For those who may be relatively unfamiliar with the present NBS services, the term *GOES,* as used in the questionnaire, refers to the Geostationary Operational Environmental Satellites that broadcast the NBS time code. *DUT1* refers to information included in NBS broadcast formats that provides the approximate difference between the UT1 astronomical time scale and the UTC atomic time scale. *Marine Weather* refers to the marine storm warning announcements provided on WWV and WWVH, and *Geoalerts* refers to the WWV announcements relating to solar activity and solar-terrestrial conditions. *Omega* refers to the WWV and WWVH announcements that relate to the current status of the U.S. Coast Guard's Omega Navigation System. *BCD Time Code* refers to the time-of-day information in binary-coded-decimal form provided on 100-Hz subcarriers on WWV and WWVH.

Please cut out and mail your completed questionnaire to the Time and Frequency Division, 524.00, National Bureau of Standards, 325 Broadway, Boulder, Colorado 80303. (No postage is necessary if mailed within the United States.)

United States Department of Commerce, National Bureau of Standards, 325 Broadway, Boulder, Colorado 80303

the TEXNET packet-switching network

part 3: software overview

Z-80 assembly language software offers multi-node, multi-user versatility in real time

In previous installments of this three-part series,[1,2] we described network algorithms and the design and testing of network hardware. This month, we'll discuss node control software.

Contained in a single 27C256 ROM, the software determines the functions and user features offered by the network nodes. Highly modular in design, the software was written in Z-80 assembly language for two reasons: one, because the wide array of services offered by a single node put memory space at a premium; and two, because one or more of each node's ports would be operating at 9600 bps, therefore stressing real-time capacity.

Because space is limited, we'll discuss the functions of specific software areas rather than describe the software itself in detail. **Figure 1** illustrates a typical node, with each major software area indicated by a circled reference letter.

common logic

The common logic portion of the software package, identified as *A* in **fig. 1**, is responsible for memory allocation and management, real-time scheduling, and interfacing to the various hardware I/O devices, such as SIO's and the CTC. As an example of these housekeeping tasks, let's look at memory management. Because there are many more users for memory than there is memory capacity, memory management — specifically in regard to time-sharing — is critical to efficient system operation. The generic problem with most memory management schemes, however, is *deadlock*, which occurs, for example, when a memory user has some memory allocated and needs more to complete the job, but can't get more because of what's already been assigned. The node software package follows a procedure known as *load shedding* to prevent deadlock; it does this by finding the "oldest" and largest consumer of memory and aborting his resource allocation.

The largest section of the common logic is the multi virtual connection PAD (Packet Assembly/Disassembly) logic. This general-purpose software has a standard interface to the higher layers of software wishing to use its services. The PAD is completely state table driven and currently implements the ARRL AX.25 V1.0 and V2.0 protocol specification. The PAD supports a variable number of simultaneous virtual connections

Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5EG, Texas Packet Radio Society, P.O. Box 831566, Richardson, Texas 75083-1566

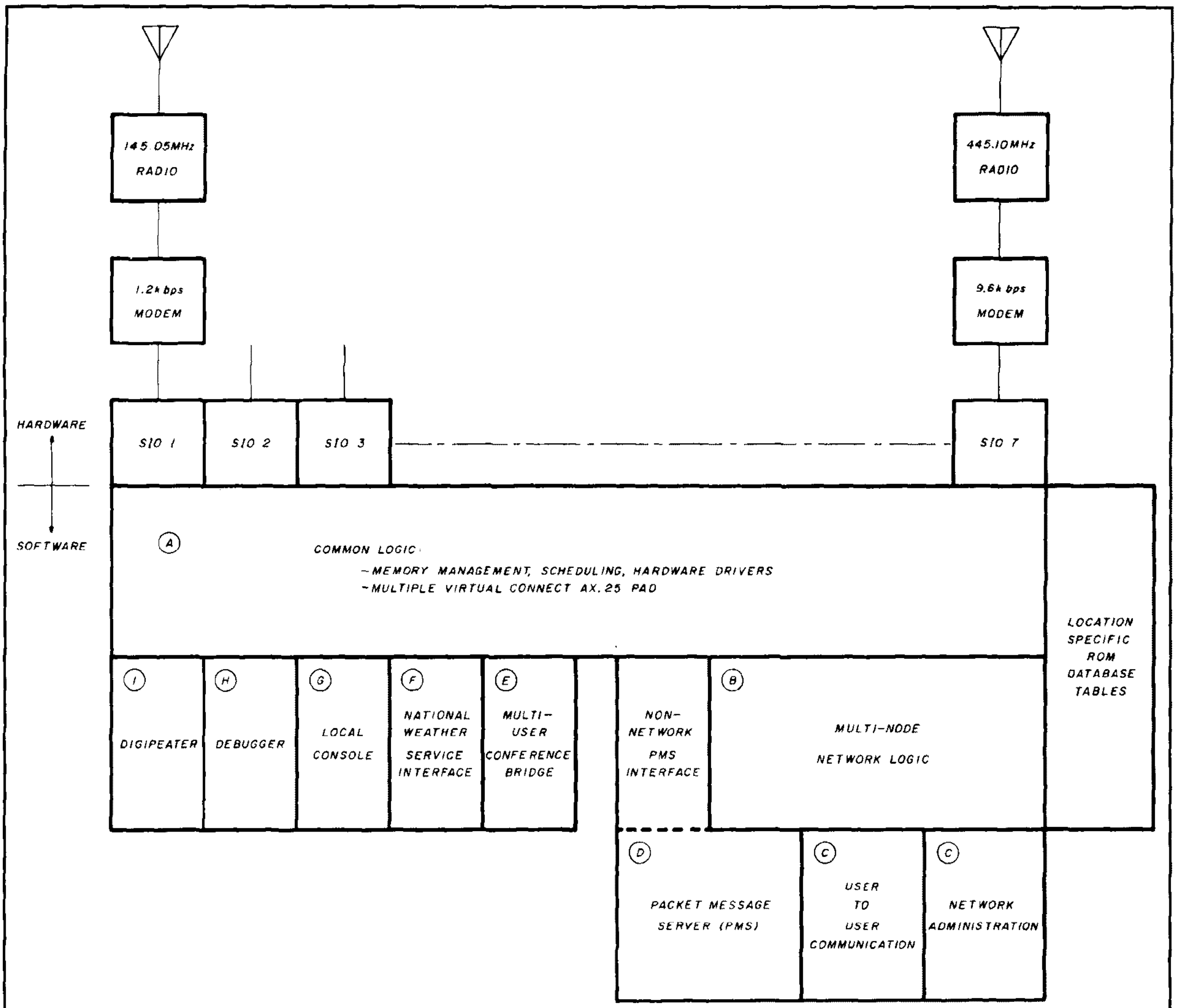


fig. 1. Node software block diagram shows hardware/software boundary and layering of various software functions.

(currently set to 20), with any of the virtual connections conforming to either V1.0 or V2.0 of AX.25. Selection of V1 or V2 operation is determined by the users' setting of their TNCs — for example, if they're running V1, then the node will act like a V1 TNC when they connect. Users running V2 will see the node as a V2 device.

The PAD, which supports up to eight physical communications channels (four SIO's), has been tested in a multiport configuration with both 9600 bps and 1200 bps, operating simultaneously without loss of data. In order to achieve this performance level for 9600-bps operation, a nested interrupt structure (the interrupt service routines are themselves interruptible) which would allow timely response to interrupts from the 9600-bps port(s) had to be designed.

The common logic provides a number of features of the node. All users of the node see the node as a series of AX.25 addresses. For example, this is how users see the Garland, Texas node:

W9DDD-2 1st conference bridge
W9DDD-3 2nd conference bridge
W9DDD-4 TEXNET Access
W9DDD-5 Node's local console
W9DDD-6 Test access

These applications will be explained shortly; what's important to note here is that all of the addresses have the same Amateur call, W9DDD, and that the application is selected according to the SSID. (This method of operation is only one configuration of the address database. Instead of using the same call (W9DDD) five

times, different calls could have been configured, with the SSID held constant. The node will support any combination of the above examples.)

The common logic also supports various restriction and parameter tables. New connections to any AX.25 address of the node can be inhibited as a function of the number of digipeaters used to get to the node. This has been found to be useful in reducing channel congestion attributable to excessive retries on long digipeater paths to a specific node. The preferred method is to put a network node near enough to the user group and carry the traffic on the network backbone trunks.

Parameters managed by the common logic, on a per-physical port basis, include all of those specified in the AX.25 protocol (i.e., T1, T2, T3, K, N2, etc.) and some unique to this application. It was found desirable to define the AX.25 T3 timer as either an all-seems-well timer (its original function) or an auto-disconnect timer. In the auto-disconnect mode, if a user's virtual connection is idle for greater than the T3 time value (nominally 3 minutes) he or she is automatically disconnected from the node, thereby making room for other users. This mode can be overridden by the ALERT network mode, which will be discussed below.

Finally, the common logic is responsible for gathering statistics for the node. Two main groups of statistics are collected. The first are those that aid in "traffic engineering" the node. Quantities such as the amount of memory in use, the maximum amount ever used, and the total available allow visibility into the level of service being provided and indicate whether or not more RAM should be allocated to the free memory pool, thus decreasing memory space available for applications. Experience indicates that a free memory pool of approximately 30K, allocatable in about 200-byte chunks, provides good service with enough reserve capacity to handle rather large impulse loads, such as congestion on 9600-bps trunk circuits.

The second group of statistics collected are those having to do with node use. Quantities such as the number of frames transmitted, received, and retransmitted for each physical channel yield data on overall network use, thereby suggesting possible additions to the node or changes in network configuration. These numbers can also be used to determine the performance level of network trunks.

multi-node network logic

As illustrated, the multi-node network logic (see *B* in **fig. 1**) is supported by the common logic. In turn, it supports higher-level applications such as Network Administration, User Intercommunication, and the Packet Message Server.

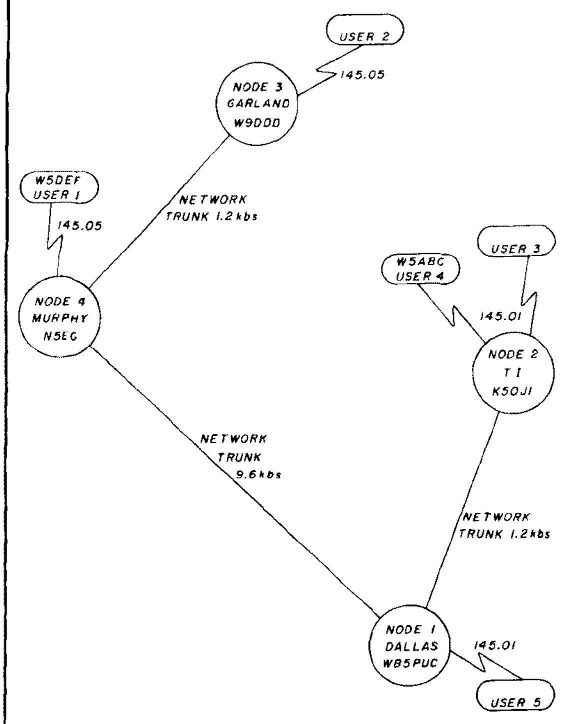


fig. 2. Dallas network test configuration.

The multi-node network logic is a datagram-based system that can support up to 256 node locations with as many as 20 simultaneous users at each node. All network nodes interconnect via permanent virtual connections between them.

The network is a database-driven system that features an extremely user-friendly termination-based routing structure. The network provides end-to-end flow control to eliminate internal congestion. A user's TNC "going busy" causes a network message to be sent to the far node, which in turn will "busy" the subject port at the far node, thus causing the remote user's TNC to stop sending.

In order to allow for an increased level of reliability, the network allows for *alternate routing* of data via multiple routes to a single node. Controlled by the node's database, alternate routing is automatically performed upon detection by a node that its first-choice route has failed.

The network provides substantial feedback to the user community via a mechanism called *Network Information Codes* (NIC). These NICs are printed at a user's terminal when something unusual happens that will affect the performance of the network from the user's viewpoint.

For an example of NIC operation, and for further

illustration and explanation, see **fig. 2**, which illustrates the network test configuration as it was in Dallas when this article was being prepared. This test configuration was used for software testing during the development phase and for a series of operational tests during the beta-test phase.

The system shown in **fig. 2** is located in the north Dallas area. No particular attention was paid to the geographical locations except for convenience of access for testing. The illustrated network architecture was chosen because it provides for testing of all possible configurations of actual network operation.

Each of the four nodes has an Amateur call sign assigned as its user-access AX.25 address. Each node also has a mnemonic name to which all users refer when asking the network for services. For example, Node 4 has a user-access address of N5EG-4, and is referred to by users in all network commands as MURPHY. (Note: MURPHY is named for its location in Murphy, Texas — not in honor of the universal law of the same name.)

In an actual geographically dispersed network, the user community around each node has to know only their own node's user access address (N5EG-4 in the example above). They refer to all other nodes in the network by the network node names (GARLAND, *MURPHY, DALLAS, TI [Texas Instruments Radio* Club] — see **fig. 2**).

Also shown in **fig. 2** are typical user stations, labeled User I through User 5. These stations are standard Amateur packet stations equipped with commercially available TNCs and VHF transceivers.

the network users' interface

The Network Users' Interface (see *C* in **fig. 1**) provides the user's view of the network. Referring to **fig. 2**, if User 5 were to connect to WB5PUC-4, he would see the following displayed on his screen:

C WB5PUC-4
*****Connected to WB5PUC-4**
WB5PUC-4 Virtual Connection 06 at 18:32:20 on 11/20/86
*****Welcome to TEXNET*****
Network Cmd?

At this point he can issue any of the network commands or just disconnect if he's finished.

network command structure

The network command structure is as follows:

• **@NODENAME.** The NODENAME field may consist of any valid network node name. Valid node names may be two to seven characters long and can consist of any ASCII character except carriage return. As indicated in **fig. 2**, these names are MURPHY, GARLAND, TI, and DALLAS in our test configuration. User entry of a name not recognized by the node as valid will result in a message to the user indicating that an invalid node name has been entered. A list of valid names will be printed to allow correction of the error.

Because any command may be destined for any node, most commands are terminated by the @ NODENAME field. Some commands have an implied node name. Commands that are currently implemented are listed in **table 1**. For purposes of this description, the network commands are divided into two categories: User and Administration. Note that this division is for explanation only; any user may execute any command. Those who simply want to communicate via the network need learn only the commands listed in the User category. A much smaller group of people — those who are responsible for network engineering and administration — need to learn the Administration commands.

While the command words are spelled out fully in **table 1**, only the first character must be entered for most commands — for example, ***H*** for *HELP*. **Table 1** includes examples of network commands and their abbreviated formats.

• **HELP.** The user entering this command is given a partial list of commands (those marked "user") and referred to the network operation manual for further enlightenment. This strategy, rather than the on-line tutorial method, was chosen in order to reduce channel congestion. All new users are sent a copy of the TEXNET manual; this eliminates trial-and-error learn-

Table 1. Active network commands can be typed by user in response to the network command prompt, which is received after the user does a standard connect to the node.

Type	Command	Parameters () = optional input	Example using abbreviated command
User	Help	None	H
User	Circuit	Call sign (via Digi)	C W5ABC @ Dallas C W5ABC V WA5LXS @ Dallas
User	Locations	None	L
User	Message	None	M
User	Alert-on	None	A -on
User	Alert-off	None	A -off
Admin	Statistics	None	S @ Dallas
Admin	Initialize	None	I @ Dallas
Admin	Time	(DDMMYYHHMM)	T @ Dallas T 0108871420 @ Dallas
Admin	Route add	26 bytes of information	R A 01 . . . . 7F @ Dallas
Admin	Route delete	Number	R D 2 @ Dallas
Admin	Point	Function number	P E 2 @ Dallas P D 2 @ Dallas P S @ Dallas

ing on the air, which results in more efficient use of channel space.

• **The CIRCUIT** command tells the network the desired destination of the user's connection. See **fig. 2**; if User I wanted to communicate with User 4, he would enter the following at the command prompt:

C W5ABC @ TI

Obviously, this example assumes that User 4's call sign is W5ABC. Note that User 1 doesn't need to know how the network will connect to User 4; he just enters the terminating node name TI, and it's the network's responsibility to figure out how to route the message to TI.

The routing strategy is accomplished by the database in a node's knowing which of its adjacent nodes should be used to get to a remote node. It's a tradeoff, in that it makes the node database somewhat more complex — but it does allow the users an extremely easy interface.

Because the users don't need to know the physical configuration of the network in order to communicate, the network administration group can change it at will without having to inform (and thus re-educate) the entire user community. This routing strategy takes advantage of the disparity between the number of times users access the network to communicate (very large) versus the number of times the administration group adds or makes changes to a node (very small). The increased burden on the administration group is more than offset by the benefit to users.

In order to compensate for incomplete geographic network coverage, the CIRCUIT command allows an optional string of digipeaters to try to connect to the desired station. Thus,

C W5ABC V WA5LXS @ TI

would cause the remote node TI to attempt to connect to W5ABC, using WA5LXS as a digipeater. Up to two digipeaters can be specified in the CIRCUIT command.

Operations note: whenever a remote node attempts to connect to a station (as when TI attempts to connect to W5ABC in our example), the node will use Version 2 of the AX.25 protocol unless a digipeater is specified. If a digipeater is specified, the remote node will attempt the connect using Version 1 AX.25. This is because there are still some digipeaters around that won't accommodate Version 2.

After User I enters the CIRCUIT network command, one of three things will happen. First, his CRT may display the message,

Your connection is established

in which case he's being advised that the desired remote user (User 4) is on line. At the far side, our remote user (User 4) would receive the following on his screen:

*****Connected to K5OJI-4**
*****Linked to W5DEF at Murphy via Texnet**

Therefore, User 4 knows exactly to whom he is connected via the network, and where the originating station is located. The above example, of course, assumes User 1's call is W5DEF.

The "**** Linked to" string received from the network allows a WØRLI-compatible BBS system to know who the real user is (W5DEF) rather than thinking it is connected to the node (K5OJI-4).

The second possible message is:

Remote user not responding

In this case, User 1 is informed that connection is impossible. This could occur for a number of reasons: the remote station may not have its equipment turned on, or it may be turned on but involved in another QSO.

The third possibility is receipt of an NIC message. Using our example, if user 1 received:

Network information code 017 from Dallas

he could look in the TEXNET manual and find that code 017 means his attempt was routed as far as Dallas, but couldn't be routed further because of a network trunk outage. This can then be reported to network administration for remedial action.

• The **LOCATIONS** command allows users to ask the node for a list of remote locations which can be reached through the network.

• **The MESSAGE** command gives any network user, regardless of node location, access to the network Packet Message Server (PMS) logic. Details of the PMS subsystem will be covered below; for the moment, let's just say that it's a network-wide message file system similar to the W0RLI bulletin board system.

It's important to note that users at any node in the network don't need to know where in the network the PMS system is physically located. All a user needs to do is type MESSAGE or M, and the network takes care of routing to PMS. In the test configuration shown in **fig. 2**, PMS is actually located at Node 1 or Dallas, but very few users are aware of this, since they can connect to any node to access PMS. Once the network has established a connection for the user to PMS, the user can enter PMS commands to store, list, or read messages.

• **ALERT-ON** AND **ALERT-OFF** enable or disable a special mode of operation called ALERT, which is especially designed for accommodating emergency traffic handling via packet radio. The ALERT mode can be enabled from any node in the network. When a user

connects to any node and issues the ALERT-ON network command, his or her node will send a "broadcast" command to all other nodes in the network informing them that ALERT mode is being enabled and telling each the name of the originating node. At this point, several things happen in every node.

Users connecting to the network are informed that an ALERT is in progress. Let's assume that a user at Dallas has enabled the ALERT mode. As in our previous example, User 1 wants to communicate with User 4; when he tries to connect, however, he receives the following message on his CRT:

*****Connected to N5EG-4**
N5EG-4 Virtual Connection 03 at 08:30:20 on 12/15/86
Pls disconnect unless your traffic is related to the network alert in progress from Dallas.
****Welcome to TEXNET****
Network cmd?

When ALERT is enabled, all user automatic disconnect timing is disabled. Thus, instead of the standard 3-minute idle time disconnect, to which all users are subject, all nodes will allow connections of unlimited duration to their ports. This disconnect timing suspension affects all connects to the node. Thus, if groups of users want to use their node's conference bridges to handle emergency traffic, they can remain connected indefinitely. User connects to PMS may also be of indefinite duration.

With the enabling of ALERT, a special mode of PMS that provides a real-time message exchange between the multiple users connected to PMS is also enabled. Thus, when one user SENDS (see PMS description below) to another, all of the standard PMS functions are invoked. In addition, after automatically saving the message on disk, PMS will check to see if the addressee is currently connected to PMS on another of its logical ports. If he is, PMS will automatically display the message at the addressee's terminal.

With this mode of operation enabled, PMS becomes a real-time message forwarding system among its connected users, with the added feature that all messages are archived to the disk. This feature can be extremely useful in emergency government communications back-up, since the stations connected to PMS could be physically located anywhere along the network.

For a Department of Public Safety (DPS) exercise, for example, Amateurs equipped with standard packet equipment could be located in each community's DPS office. Each station would be connected, via the network, to one of the logical ports of PMS. Because the ALERT mode would be enabled, they would be able to stay connected indefinitely — remember, DISC (disconnect) timing is inhibited with the enabling of ALERT — and each time one station uses the standard **S** feature of PMS, the message would be displayed in real time at the receive station. Of course, the message would be automatically saved to disk so the receive station can review it at will. Other advantages of this technique include a complete on-disk record of all messages (useful for exercise postmortems) and the fact that other connected stations may review all communications except those sent as private messages.

• **The STATISTICS** command, when issued with the NODENAME parameter, causes the local node to acquire the operational statistics of the remote nodes. The statistics counters in a node aren't cleared by this command; this allows timed interval measurements to be taken. Every midnight, all statistics counters are cleared to zero.

The following are the statistics kept at each node and therefore available via the STATISTICS command:

Frame buffers available
Frame buffers in use
Maximum frame buffers ever used
Total connects
Connects to weather
Connects to conference bridge
Connects to network
Network circuits active
Maximum network circuits ever active
Packets sent on each physical channel
Packets received on each physical channel
Packets re-sent on each physical channel

In addition, the real time at the subject node is sent back with the statistics. By looking at some of the statistics returned, the network administrators can make various engineering judgments about the level of service being provided by a node to its user community. Quantitative measurements of the activity of a node's local user community, and of which node services are being used, can also be made.

• **The INITIALIZE** command is the means of remotely restarting any node. When a node receives an INITIALIZE command directed to it from someplace on the network, two functions are executed. First, upon receipt and decoding of the command, the software kills all activity in the node for 30 seconds. This delay allows time for adjacent nodes to have their network trunks to the subject node time out because of the subject nodes' lack of activity. This action gracefully removes the subject node from the network fabric. At the end of the delay period, the subject node does a cold restart, thus appearing to the rest of the network as if it had just been turned on. In response to this action, the subject node — after consulting its database — establishes network trunks to the appropriate adjacent nodes. Network operation is now re-established.

The second thing that happens upon receipt of an INITIALIZE command is the activation of an external hardware fail-safe circuit. Buried in the INITIALIZE command as it traverses the network is a unique bit sequence generated by the originating node and specific to the subject node. Upon detection of the bit sequence by the subject node's external hardware fail-safe circuit, the master reset line of the Z-80 is asserted. This technique obviates the above discussion on the software execution of the INITIALIZE command unless, of course, there's a failure in the fail-safe hardware itself. The combination of the two techniques would require a double failure in a node before the ability to remotely reset it would be lost.

• **The TIME** command, when issued by a user at any node and directed to a specific remote node, will cause the real-time clock at the remote node to be updated to the time contained in the message. If no time parameter is input by the originating user, then the current time at the user's node is sent to the remote. If the time parameter is entered by the user, his or her node's real-time clock is updated with the input time before its value is sent to the remote node.

• **ROUTE ADD/DELETE**. Since in every node the ROM routing table is copied to RAM for operation, it may be changed by being added to or deleted from. The ROUTE commands are the means by which new nodes can temporarily be added to an existing network or by which the network configuration can be changed to accommodate a failure or some other special event.

• **POINT** COMMAND. This command is used to control external equipment at any node site. Within each node control point (NCP), there are 5 bits of input and 5 bits of output available for external use. These bits, called control points, could be used to control and monitor anything that interfaces via contact closures. Co-located equipment at the node site, such as other repeaters, could take full advantage of digital control via this feature of the NCP.

The POINT command allows full on/off control of the output points. For example, suppose a co-located voice repeater at the GARLAND node needed to be controlled. NCP output Point 1 could then be wired to the voice repeater's control relay, and perhaps NCP input Point 1 would be wired to one of the control relay contacts to allow monitoring of relay closure.

Any authorized packet station, anywhere on the network, can issue the following command to enable the co-located voice repeater:

POINT ENABLE 1 @ GARLAND

or for short,

P E 1 @ GARLAND

Displayed on the CRT — after the network has passed the POINT command to the GARLAND node and the command was executed — would be:

Control Points at Garland Are

Point:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Input:	**E**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Output:	**E**		**D**	**D**	**D**	**D**	**D**	**D**

Since the control operator knows that Control Point 1 is wired to the voice repeater, he can see that it's enabled, and by looking at Input Point 1, confirm that the control relay is closed.

Any time the control operator wishes to check if the voice repeater is on, he needs only to type **P S @ GARLAND** to get the status display of the control functions. When he chooses to shut the voice repeater down, he enters **P D 1 @ GARLAND** at the network command prompt. Again the status will be displayed on his screen in response to the command, allowing confirmation that shutdown has occurred.

One important use of the POINT command is the control of a pair of control points wired over to the node's Uninterruptible Power Supply (UPS). By design, the UPS has a control lead which, when enabled, forces the UPS to switch from ac to battery. Another UPS lead provides an indication that the UPS has switched to battery operation.

In a normal node configuration, Control Point 5 input and output are wired to the UPS control leads. This allows any node in the network to be instructed to operate off battery power by the simple issuance of the **P E 5 @ Node** command. Issuing the **P D 5 @ Node** command restores the node to ac operation. This feature allows weekly testing of the UPS to ensure that it would be effective during an emergency.

network internals

It may be interesting at this point to describe some of the internal workings of the network software, which has the ability to establish, kill, and communicate over any number of virtual connections. Thus, at system startup, the network application executes logic to find out who its neighboring nodes are. It then establishes a virtual connection to each, over whatever physical channel is specified to be used as the network trunk. This virtual connection is left up forever. All subsequent communications from this node to its neighbor, whether user data or network management data, travel over this permanent virtual connection. Additional logic determines the network configuration for the node's routing table.

A special byte string is added to the beginning of all packets going over a network trunk. This string, known as a *Network Header Block* (NHB), consists of a minimum of 5 bytes:

NHB.RNN	**Destination Node Number**
NHB.RLC	**Destination Virtual Connection Number**
NHB.LNN	**Originating Node Number**
NHB.LLC	**Originating Virtual Connection Number**
NHB.NCF	**Network Control Field**
~ ~	**Any Network or User Data**

When a node receives information from a virtual connection marked as a network trunk, it examines the NHB. Looking at NHB element **NHB.RNN**, it checks to see if the received string is for this node. If it isn't, the node consults its routing table to see on which of its trunk circuits (virtual connections) it is to retransmit the string. This is known as *transit routing*, and it's extremely fast, thereby yielding a large node bandwidth in this mode. If the examination of **NHB.RNN** confirms that the string is for this node, the **NHB.NCF** byte is decoded to tell the node the proper action to take on the received string. There are over 15 valid network control fields in the current design, so it wouldn't be practical to cover them all here; therefore, we'll choose just one as a simple example.

The example will be of a remote node (perhaps many hops, or nodes, away — we don't know, and we don't care if the information came to us via transit routing through multiple nodes) asking us to send our operational statistics. When we finally receive the string, we find it's directed to our node; moreover, after examining the network control field, we see it is set at 01 HEX, which tells us that the remote wants us to send our collected statistics. Our response to this is to reverse the NHB items so we can send information back to the requester and reset the network control field to 02 HEX, which will inform the requester, when he receives the string, that we responded. We append approximately 40 bytes to the string. These appended bytes are the operational statistics we've been collecting, which is what the remote requested.

the packet message server

The PMS logic (see *D* in **fig. 1**), resident within a node, allows a simple three-chip interface to a Western Digital WD 1002-05G disk controller and a standard ST506 5-Megabyte hard disk to become a network wide integrated message storage/retrieval system. Normally, only one disk is required per network. It's possible, however, in a very large network, to assign specific groups of nodes to a given PMS, in which case there could be more than one PMS disk. The PMS logic is resident in each node, but only the node(s) equipped with a physical disk allow it to execute.

From an individual user's viewpoint, the PMS looks and acts like a W0RLI bulletin board system. This choice of operational methods was made to reduce the amount of end-user training required. It also aids in the transition that must occur when all users in a given area are switching from being served by an in-place W0RLI system to the PMS system running on the network. Because of the similarities between the familiar W0RLI system and the PMS, this discussion will not cover details such as how the SEND, READ, KILL, and other commands work, but will instead concentrate on the PMS's enhancements.

Because the PMS system is designed to provide message service for all the users of a network subregion, the bandwidth requirements are greater than those found in other message systems. Unlike existing message systems, which have the ability to service only one user at a time, the PMS system allows up to ten users to log on simultaneously, providing the same grade of service, relative to response time, to each.

The storage element in a PMS is a 5-Megabyte hard disk. These disks are equipped with four head assemblies and a platter assembly capable of accommodating 154 cylinders. To make use of these characteristics and to provide the response time needed, the software was expressly designed to have a message file structure that takes advantage of the physical characteristics of the disk. The first time a new node is energized, the disk is automatically formatted and then configured to the necessary file structure. Every restart thereafter preserves all saved messages.

The combination of the hard drive and special file structure results in an incredibly small response time; even with multiple users, each user has a real-time response from the PMS, with a delay of less than 1 second. In tests run on the Dallas network test configuration, remote network users accessing the PMS via a 9600-bps network trunk observed no difference in response time from that observed by users directly connected to a PMS system. Both experienced a response time of less than 1 second. Most operational response time delay was attributable to congestion on the 1200-bps final link to the user.

The PMS system supports up to 500 active messages from a message number range of 1 to 99,999. There's no difference in response time if a user is accessing Message No. 1, 500, or 50,000.

All active messages are subject to the auto-delete function of the PMS. An undeleted message will remain in PMS for no fewer than 14 days and no more than 28 days before being automatically deleted by the system. While these times are variable, users seem to find them satisfactory.

Important note: the PMS message system is

designed to run *completely* unattended. No SYSOP is required. All duties previously performed by people running mailboxes are done automatically by the PMS logic.

The PMS system can run "stand-alone" — for example, with its user community geographically near the PMS equipment, thus replacing an existing mailbox system. In testing this configuration, a version of the software was put into an MFJ 1270 TNC-2 with a hard disk interfaced to it. This system is currently used as a demo system for other groups of Amateurs wishing to participate in TEXNET.

PMS is used primarily as a network-wide message system. In its network configuration, any user located anywhere on the network may, after receiving the network command prompt, issue only the MESSAGE command to be automatically routed over the network to his servicing PMS. Referring again to **fig. 2**, the PMS equipment (all that's required in addition to an existing NCP is the disk controller and hard drive) is physically located at Node 1 in our Dallas test system. Any user can connect to any other node by issuing a connect request to the desired nodes call and using the -4 SSID. After this, all that must be done is to issue the MESSAGE command. The next thing that appears on the CRT is the text from PMS.

Since the PMS is network-compatible, it knows who the originator is as well as where (i.e., at what node name — DALLAS, GARLAND, TI, etc.) he's located. All of this is used automatically whenever a user does an **S** command to send a message to another user. If, after doing the message send, the user does a simple **R** (in PMS, the **R** with no qualifier or number will read back the last message number), he'll see that his call and the name of his node have been automatically entered in the message header.

In order to provide a message interface between an entire network and the existing Amateur message forwarding system, the PMS supports a subset of message forwarding. All messages that network users enter into PMS and which require forwarding will be passed by PMS to a single W0RLI system for eventual forwarding by the existing systems. The identification of this W0RLI system is contained in the node's database. This same W0RLI system can also forward messages into the PMS system for reading by all network users. PMS is designed to follow the standard forwarding protocol and uses a direct access port to connect with the W0RLI system. For example, in **fig. 2**, Node 1, containing the PMS system, will access the WA5MWD BBS system in Dallas by using its WB5PUC-7 direct access port. The WA5MWD BBS system can pass messages into the network by connecting to WB5PUC-7. The WA5MWD box doesn't know it's talking to the network system; it thinks it's talking to just another standard W0RLI system.

non-network local services

The following are services provided by each network node on a standard basis. These services are independent of the network, but still extremely useful:

Multi-user Conference Bridge
National Weather Service interface
Local Node Console
Debug Aid
Digipeating

multi-user conference bridge[3]

The multi-user conference bridge (see *E* in **fig. 1**) logic allows up to six remote users to hold a roundtable conversation with each remote, with the ability to see *all text generated* by all other remotes. Each remote user has a direct AX.25 connect to a logical port on the conference bridge. Upon reception of a packet of information from one user, the bridge will make multiple copies and send one to each of the other connected users. Since each user has an AX.25 connect to the bridge, he's assured of not losing packets, since the bridge will retry upon lack of an acknowledgment from the affected remote.

As the text is being transmitted to a remote user, it's modified to show which of the other remotes originated it. Therefore, all users not only see all text from each other, but know who originated it.

In a standard software package, the conference bridge logic simultaneously supports two completely independent six-party conferences. Each of these independent conference bridges is accessed by remotes using unique SSIDs, (usually -2 and -3).

Since the bridge logic is supported by the common logic, any of the remote users may be operating in either AX.25 version 1 or 2. Text is transferred among users without regard to versions used by individual remotes.

At any time during a conference, any of the users may type **CONTROL-U**. Upon receipt of this character, the conference bridge logic will respond by sending the requester a list of call signs of all other remote users currently connected to the conference bridge. Any of the remotes may exit an established conference, and other remotes may join (on a noninterference basis) the conference in progress.

Tests conducted in the Dallas area show the conference bridge to be a cleaner and more reliable way for groups to hold multi-user roundtable connects than the UNPROTO mode available on standard TNCs. This is because of the built-in advantage of error-free AX.25 connects combined with the fact that each remote has to have a good path only to the conference bridge, not to all other users.

NWS interface

The National Weather Service (NWS) application (see *F* in **fig. 1**) runs concurrently with others at a node. Typically, one node in each region could have this application enabled and interfaced via a standard 75-wpm, Baudot-encoded, 20-mA landline to the National Weather Service.

The NWS wire feed provides raw weather data for a large geographic region. The NWS logic monitors all received data, but selects and stores only those NWS products (for example, region forecasts, severe storm alerts, thunderstorm warnings, etc.) which have their unique codes programmed into the node's database. The NWS logic currently supports 30 code sequences, with each having the ability to be from 2 to 11 characters in length. This code format is consistent with the nine-character sequence utilized as a standard by the NWS.

Remote users connect to the node's NWS logic by means of a unique SSID (usually -1). Up to ten remote users may be connected to a node's NWS logic simultaneously. Upon connection to the logic, the system will wait for the remote user to enter a single product designator — for example, a user in Dallas who enters "D" causes the node to send the current Dallas area weather forecast. Entering a question mark prints the entire list of stored product designators.

All remote users are assured of receiving the latest data because the node updates its buffers in real time, as new information is received from the weather bureau. At 2 A.M. each day, the node clears all buffers to eliminate products sent infrequently by the weather service.

local CRT console

Figure 1 (see *G*) shows the local console CRT logic "sitting on top of" the common logic. The CRT logic at each node allows a locally connected standard ASCII CRT to originate and terminate connects with any standard TNC. In operation, it uses a unique SSID (usually -5) to distinguish itself from other node services. The local console logic isn't meant to be a full TNC-human user interface, as commercial TNCs are. Instead, this logic provides a minimum subset of human user commands that are necessary for testing and administration of the node. **Table 2** contains examples of command types supported; some specific commands follow.

Table 2. Command types supported by TEXNET's CRT logic.

Command Type	Format
ORIGINATE ON PHYSICAL CHANNEL	ON where N = 0, 1, etc. = physical channel
CONNECT	C W5ABC V WA5MWD, N5EG
DISCONNECT	D
BUSY	B
FRAME TRACE	FT
LOCAL TIME SET	LT DDMMYYHHMM
STANDARD MODE	SM
VERSION SELECT	V1

• **The ORIGINATE ON PHYSICAL CHANNEL command** allows the user to select which physical channel is to be used for originating connects. The console will accept connects from any physical channel, but will do so only if it's not currently busy. This command allows the console to originate on the physical channel connected to the 1200-bps radios and, therefore, look like a standard user. Also allowed are connections to be established to any other node site via the 9600-bps trunk circuits. The latter is particularly useful for troubleshooting remote nodes from our network control site.

• **CONNECT AND DISCONNECT** are identical to the commands on any standard TNC.

• **BUSY** sets the console into a busy state to facilitate troubleshooting the network's end-to-end flow control logic.

• **FRAME TRACE** is similar to that command on any standard TNC in that it provides a real-time look at all frames as they're received by any physical channel on the node. Displayed are both hex and ASCII equivalents of the received frame.

• **LOCAL TIME SET** allows maintenance personnel to reset the real-time wall clock at a node. This command usually isn't used because it's possible to set the time at any node in the network from any other node using the network TIME command.

• **STANDARD MODE** permits an unused bit in the standard AX.25 protocol to be toggled. This bit is utilized by the PAD logic, network logic, and debug logic to signify that the remote is a special user capable of accessing advanced functions.

• **VERSION SELECT** allows the local console to originate connects in either AX.25 V1 or V2. This command controls only the originating version, since the common logic automatically accommodates either version on terminating connects.

The local console CRT interfaces to the NCP via one half of an SIO, which can be strapped for multiple baud rates. The console employs a 1000-character buffer to accommodate the speed differences between incoming text and the rate of display. Because the local console need not be equipped on a node, the console logic handles cases where no hardware is present.

Table 3. Some commands and functions supported by the debug logic.

Command	Format	Description
MEMORY	M Adr1,Adr2	Do a hex dump from memory location Adr1 to Adr2.
	M Adr1	Display the contents of memory location Adr1 and then wait for new contents to be entered. Entering a period escapes this mode.
COPY	C Adr1, Adr2, Adr3	Copy the contents of memory locations Adr1 to Adr2 to the new location, beginning with Adr3.
*(OFFSET)	* Adr1	The offset (*) register is useful for input arithmetic. For example, setting the * register to 1000H (*1000) allows subsequent entering of M*+2 to display location 1002H.
HEX ARITH	H Num1 + Num2 - Num3	Perform hex arithmetic on any entered numbers. Addition and subtraction are supported with support of the offset (*) register.
PORT	P75	Display the contents of the Z-80 I/O address 75H, then wait for a new number to be input. Entering a period escapes this mode.
INITIALIZE	I Adr1, Adr2, Num	Initialize the memory block from Adr1 to Adr2 with the number (Num) entered.
EXECUTE	E Adr1	Transfer execution control to Adr1 with the Z-80 registers initialized per the "R" command.
REGISTER	R	Display and allow change of the Z-80 register file
X DIAGNOSTIC	X Adr1, Adr2	Run read/write/verify memory diagnostics on the memory block Adr1 to Adr2.

debugger

The debug logic (see *H* in **fig. 1**) has proved to be an invaluable aid in initial software debug as well as in system integration. The debugger at any node is accessed by specially authorized remote users via requesting a connect to the node utilizing a given SSID (usually -6). This logic supports a single user and inhibits others from connecting if someone is currently active.

The debugger executes concurrently with the network logic and the PMS, as well as at the same application level (see **fig. 1**). Accessed from the common logic, it is used as an aid in debugging these and other applications in an on-line manner.

Table 3 describes some of the commands and functions which are currently supported by the debug logic.

digipeating

Unless inhibited from doing so by the database, every network node can also function as a local digipeater (see *I* in **fig. 1**) for whatever frequency is being used as an input. In Dallas, it's 145.05. Multiple digipeater addresses are supported, thus allowing for any number of ALIASES or standard AX.25 addresses. It should be noted here that the PAD addresses mentioned above and the digipeater addresses are completely separate.

Enhanced digipeating is supported by the node because the output physical channel for retransmission of a packet is a function of both the digipeater address and the physical channel on which the packet was received. Thus, it's possible to have a cross-frequency digipeater using no special tricks or logic. For example, N5EG-8 (Node 4, MURPHY) is configured to be a bidirectional cross-frequency digipeater between 2 meters and 450 MHz. This has proven to be extraordinarily useful in network software construction because it allows access to a remote node (one which is potentially many hops away) via digipeating over the 9600-bps trunk circuits. This method of access completely bypasses all other software and is, therefore, useful (in conjunction with the debugger) in troubleshooting.

conclusion

Thanks to the members of the Texas Packet Radio Society for helping to make this series of articles possible.

We'd like to hear from developers and users of other packet systems to learn what you're doing. Please address correspondence (enclose SASE) to Tom McDermott, N5EG, The Texas Packet Radio Society, P.O. Box 831566, Richardson, Texas 75083-1566.

references

1. Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5EG, "The TEXNET Packet Switching Network: Part 1 — System Definition and Design," *ham radio*, March, 1987, page 29.
2. Thomas H. Aschenbrenner, WB5PUC, and Thomas C. McDermott, N5EG, "The TEXNET Packet Switching Network: Part 2 — Hardware Design," *ham radio*, April, 1987, page 29.
3. Bill Wade, WD5HJP, "Packet Radio Conference Bridge," *ham radio*, April, 1987, page 24.

ham radio

DX FORECASTER

Garth Stonehocker, KØRYW

sporadic-E season

During the summer months the sun — directly overhead at 23 degrees north — produces more ions in the lower ionosphere than it does in winter. These abundant ions are formed into cloud-like patches known as sporadic-E. The patches, which form in a thin but dense layer about 60 miles above the earth, give rise to strong mirror-like signal reflections over short-skip distances of 600 to 1200 miles.

Because E_S is related to the summer sun, the best locations for working these E_S openings are in the Northern Hemisphere from June through September and in the Southern Hemisphere during their summer, December through March. In each hemisphere, the best E_S is found on either side of the geomagnetic equator; it's especially good where the geomagnetic equator is furthest from the geographic equator. These special areas are Southeast Asia and the Mediterranean in the Northern Hemisphere and South America in the Southern Hemisiphere, with the former the better, as shown in **fig. 1**. The contours in the figure represent the percentage of the time sporadic-E is available along that line. A "10-line" indicates that sporadic-E is available 10 percent of the month, or three days out of 30 — or, equivalently, 6 minutes out of each hour. This is a purely statistical measure of the chance of an E_S patch being available at the location of the midpoint of a 2000-km path. E_S openings can be utilized as high as the 6-meter band this year.

last-minute forecast

During the first two weeks of the month, daily MUFs should be lower. As a result, fewer openings on 10 to 30 meters can be expected, except for a few sporadic-E short-skip paths. There's a slim possibility of one occurring on 6 meters. Long-skip conditions on these bands will improve somewhat in the third week. The lower bands will be best for daytime short-skip paths during the second week, corresponding to a minimum solar flux in June. Nighttime DX conditions should be best then as well, and should be fairly good during the whole month except when atmospheric noise levels are high.

The moon will be full and at perigee (its closest approach) on June 11. Summer solstice is on the 21st at 2211 UTC. The Aquarid meteor shower starts about the 18th, peaks about the 28th, and lasts until about August 7. The maximum radio-echo rate will be 34 per hour.

band-by-band summary

Six meters will provide occasional openings to South Africa and South America around noontime via short-skip E_S propagation.

Ten meters will provide long-skip conditions in the afternoon during the peak times of the 27-day solar cycle. Otherwise, look to sporadic-E short-skip and multihop openings around local noon for DX on this band. (Transequatorial evening openings usually don't occur in the summertime.)

Twelve and fifteen meters, almost always open to some southern part of the world, will be the main daytime DX bands. Operate on 12 first, then move down to 15 later. DX is considered 5000 to 7000 miles on these bands. There may be some long one-hop transequatorial propagation early in the month.

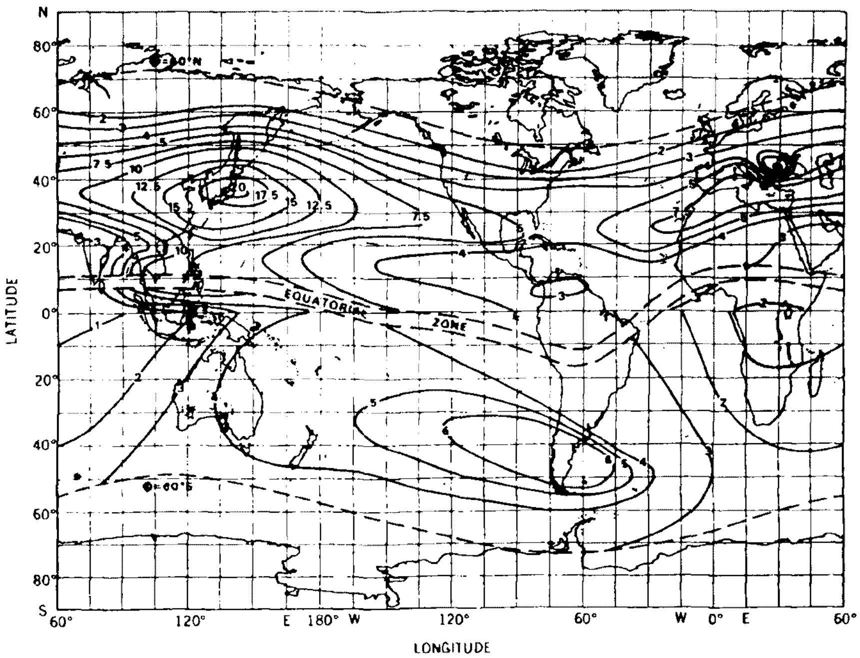


fig. 1. World map includes sporadic-E contours. The numbers on each line represent statistically the percentage of time during the month that a sporadic-E patch exists at that location.

WESTERN USA

GMT	PDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)
0000	5:00	20	30	20	12	20	15	10	15
0100	6:00	20	30	20	15	20	12	10	15
0200	7:00	20	30	30	15	20	10	10	15
0300	8:00	15	30	30	20	20	10	10	15
0400	9:00	20	30	30	20	30	10	10	15
0500	10:00	20	20	20	20	30	12	12	15
0600	11:00	20	20	15	20	30	12	15	15
0700	12:00	20	20	15	20	30	15	15	20
0800	1:00	20	30	20	20	30	15	20	20
0900	2:00	30	30	30*	30	40	15	20	20
1000	3:00	30	30	20	30	40	20	20	20
1100	4:00	30	20	20	30	40	20	20	30
1200	5:00	30	20	15	20	40	20	20	30
1300	6:00	20	20	12	20	40	30	30	30
1400	7:00	20	20	12	15	40	20	30	20
1500	8:00	20	20	10	12	40	30	30	30
1600	9:00	20	20	10	12	40	30	30	40
1700	10:00	20	15	10	12	30	20	30	30
1600	11:00	30	15	12	12	20	20	30	20
1900	12:00	30	15	15	12	20	15	20	20
2000	1:00	30	20	15	10	20	12	12	20
2100	2:00	30	20	20	10	20	15	12	20
2200	3:00	20	20	20	10	20	12	10	20
2300	4:00	20	20	20	12	20	12	10	20

JUNE

MID USA

GMT	MDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)	CDT
0000	6:00	20	20	20	12	20	15	10	15	7:00
0100	7:00	20	30	20	15	20	12	10	15	8:00
0200	6:00	20	30	30	15	20	10	10	15	9:00
0300	9:00	20	40	30	20	30	10	12	15	10:00
0400	10:00	20	30	30	20	30	12	12	20	11:00
0500	11:00	20	30	20	20	30	12	15	20	12:00
0600	12:00	20	30	20	20	30	12	15	20	1:00
0700	1:00	30	20	20	20	30	15	15	20	2:00
0800	2:00	30	20	20	20	40	15	20	20	3:00
0900	3:00	30	20	30*	30	40	15	20	30	4:00
1000	4:00	30	30	20	30	40	20	20	30	5:00
1100	5:00	20	30	20	30	40	20	20	30	6:00
1200	6:00	20	20	15	20	40	30	20	20	7:00
1300	7:00	20	20	15	20	40	30	30	20	8:00
1400	8:00	20	20	12	15	40	30	30	20	9:00
1500	9:00	20	20	12	15	40	30	30	30	10:00
1600	10:00	20	20	10	12	40	20	30	30	11:00
1700	11:00	20	20	10	12	30	20	30	20	12:00
1600	12:00	20	20	12	10	20	20	20	20	1:00
1900	1:00	30	20	15	10	20	15	15	20	2:00
2000	2:00	30	20	15	10	20	15	12	20	3:00
2100	3:00	40	20	20	10	20	15	12	20	4:00
2200	4:00	30	20	20	10	20	12	10	20	5:00
2300	5:00	20	20	20	12	20	12	10	20	6:00

EASTERN USA

GMT	EDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (CARIBBEAN S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)
0000	8:00	20	20	20	12	20	10	10	20
0100	9:00	20	20	20	15	20	10	10	20*
0200	10:00	20	30	30	15	30	12	12	20
0300	11:00	20	40	30	20	30	12	12	20
0400	12:00	20	30	30	20	30	12	12	20
0500	1:00	30	40	20	20	30	15	15	20
0600	2:00	30	30	20	20	40	15	15	20
0700	3:00	30	30	30*	20	40	15	20	30
0800	4:00	20	20	20	20	40	20	20	30
0900	5:00	20	20	20	30	40	20	20	30
1000	6:00	20	20	15	20	40	30	30*	20
1100	7:00	20	20	15	20	40	20	20	20
1200	8:00	20	20	12	15	40	20	20	20
1300	9:00	15	20	12	12	40	20	20	20
1400	10:00	20	20	10	12	40	20	30	20
1500	11:00	20	20	10	12	40	30	30	30
1600	12:00	20	20	10	12	30	20	30	30
1700	1:00	20	20	10	12	30	20	30	20
1600	2:00	20	20	12	12	20	15	30	20
1900	3:00	30	20	15	12	20	15	15	20
2000	4:00	30	20	15	10	20	15	12	20
2100	5:00	40	20	20	10	20	15	10	20
2200	6:00	30	20	20	12	20	12	10	20
2300	7:00	20	20	20	12	20	12	10	20

Shaded numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

PRACTICALLY SPEAKING ... Joe Carr K4IPV

build your own time-domain reflectometer

Solving transmission line difficulties can be a tedious and difficult chore, especially when the load end isn't easily accessible. Although a number of different methods of dealing with these problems are available, I want to discuss time-domain reflectometry this month; we'll cover some of the others in subsequent columns. Although commercial time domain reflectometers (TDRs) are expensive, some of the methods of time-domain reflectometry can be used by any Amateur who has access to an oscilloscope. The results won't be as good as those obtained with professional TDR equipment, but the methods will work.

TDR fundamentals

Time-domain reflectometry works on the principle that waves on a non-matched transmission line *reflect*. [Any variation from the characteristic impedance of the transmission line will cause a reflected component to be sent back to the source. — Ed.] The waveform seen at any given point along the line is the algebraic sum of the forward and reflected waveforms. In TDR measurements, we look at the waveform at the input end of the transmission line system.

Figure 1 shows the basic setup for a TDR. A pulse generator, or other source of 1-MHz square waves, is applied simultaneously to the vertical input of an oscilloscope and the input end of the transmission line. The simplest way of splitting the signal is to use an ordinary coaxial "tee" connector, either a BNC or UHF.

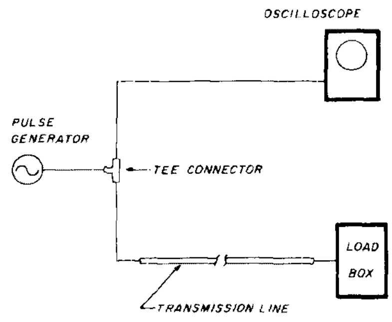


fig. 1. Time domain reflectometry (TDR) test setup shows effects of various load resistances on transmission line display.

pulse source

Almost any source of 1-MHz square waves can be used for the pulse generator. If you have a function generator with a 1 MHz or higher output pulse rate, you can use it; be careful, however, if the output impedance is 600 ohms. In such a case, you might want to wind a 600-to-50 ohm transformer or add a simple resistor pad. Alternatively, you can build your own pulse source.

building an oscillator

Many different forms of TTL oscillator can serve as a pulse source. **Figure 2A** is a circuit for a pulse generator that uses the Motorola MC-4024P device. This dual, TTL-compatible, voltage controlled oscillator is enclosed in a shielded box. The operating frequency is determined from $f = 300/C$, where f is the frequency in MHz and C is capacitance in pF. The actual operating frequency isn't terribly critical, as long as it's somewhere near 1 MHz. For very short transmission lines, the operating frequency may have to be increased. Experiment with it.

The output waveform is a square wave with a period of about 1.1 μS, with C1 = 330 pF. The half-cycle used in the experiment (see **fig. 2B**) has a duration of 550 nanoseconds (0.55 μS). If you want to clean up the rise

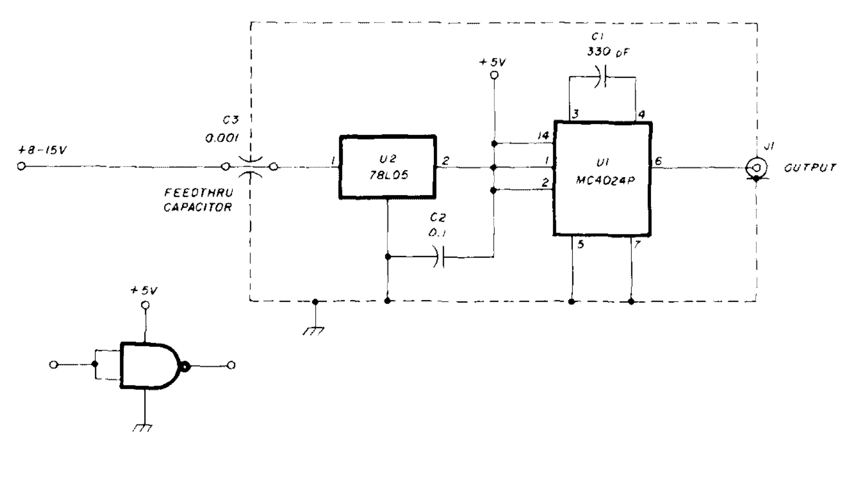


fig. 2A. TTL oscillator used as pulse generator source: circuit diagram.

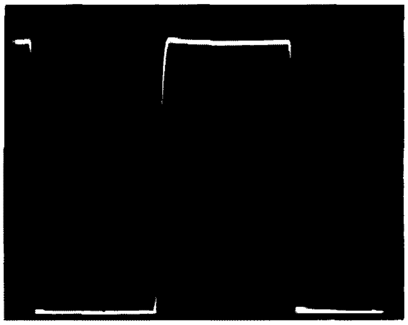


fig. 2B. TTL oscillator used as pulse generator source: output waveform.

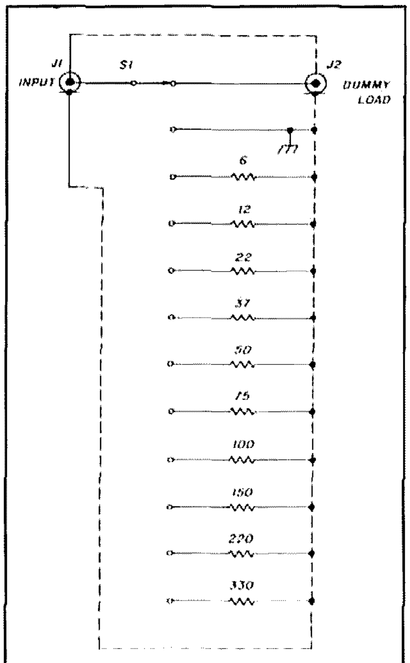


fig. 3. Test box provides various load resistances below and above characteristic impedance of transmission line.

and fall times of the output waveform, pass the output through either an inverter made from an "H" series TTL or a Schmitt trigger (7414). The inset to **fig. 2A** shows an inverter made by strapping the inputs of a 74H00 NAND gate.

Figure 2B was photographed from my oscilloscope with the coaxial cable *disconnected*. In the following photos, we'll see what this pulse looks like when a reflected pulse hits it after returning from its round trip on the transmission line.

Another alternate pulse generator is a 1- or 2-MHz crystal oscillator. These oscillators can also serve as marker generators for other purposes.[1] Another possibility would be a 20-MHz TTL crystal oscillator with cascaded TTL frequency dividers providing 10-MHz, 5-MHz, 2-MHz, 1-MHz, 500-kHz, 100-kHz, 50-kHz, and 10-kHz outputs. There's no reason the marker generator can't be used as the pulse source in TDR measurements.

test setup

The test setup shown in **fig. 1** was built to accomplish these measurements. The load box (see **fig. 3**) at the "antenna" end of the transmission line is a multi-impedance dummy load. The choices are ten discrete impedances, a short circuit, or an external load. When the external dummy load is disconnected, the load box sees an open transmission line in that switch position. (Why have a load box? It isn't part of the TDR, but it helped in calibrating the system and in generating the pictures that follow.) The impedance values shown were selected to represent a wide range of actual impedances typically encountered in Amateur antennas.

measurements

Figure 4 shows two conditions that often occur on transmission lines: open circuits and short circuits. It rarely matters which one happens; both need to be corrected at the antenna end. The VSWR reading won't tell you which one has occurred, because in either case the entire incident wave is reflected. The only difference is the location of the nodes and anti-nodes, which are out of phase with each other. If the exact electrical length of the line is known, we can determine whether the line is open or shorted. Otherwise, we'll need to make a TDR measurement.

Figure 4A shows the waveform when the load end of the line is short circuited (in other words, when Z_L is zero). In the opposite case, an open-circuited line (with infinite impedance) appears as shown in **fig. 4B**.

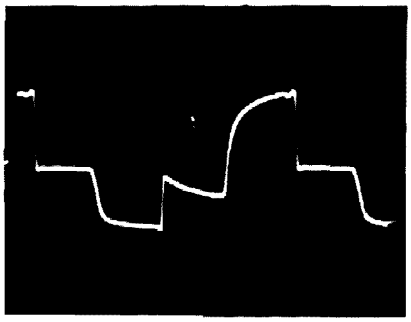


fig. 4A. Waveform seen on the oscilloscope under extreme load conditions: short circuit.

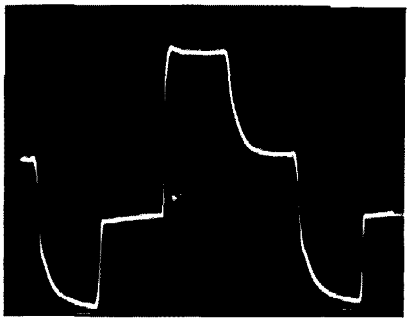


fig. 4B. Waveform seen on the oscilloscope under extreme load conditions: open circuit.

As you might suspect, impedances between zero and infinity are represented by various combinations (see **fig. 5** of the two waveforms shown in **fig. 4**. **Figure 5A** shows the supposedly matched 50-ohm case. If the system were perfect, the top edge of the pulse would be totally flat. But the actual resistor used in the load box was 51 ohms (with 5 percent tolerance). In addition, there's bound to be some reactance in the load, and perhaps some anomalies in the coax itself. When I performed this little experiment before, using a non-inductive 200-ohm potentiometer as the load, I was able to all but totally adjust out the lack of flatness. As you'll see in a moment, the waveform in **fig. 5A** represents a real load impedance greater than 50 ohms.

The waveform shown in **fig. 5B** is for a 22-ohm load. This impedance is common on vertical antennas. (The nominal impedance for quarter-wave-

length vertical is 37 ohms, but impedances will lower for shorter verticals.)

With load impedances greater than 50 ohms, the waveform takes on a different shape. Instead of the reflected impedance causing a little rise in the flat-top edge, it causes a droop. By comparing **figs. 5C** and **5D** you can see that the amount of droop is related to how far above the surge impedance the load is.

The ideas presented here work, but I'm sure they can be improved upon. If you have any ideas, let me know. (Please note new address: P.O. Box 1099, Falls Church, Virginia 22041; current *Callbook* address is incorrect).

repairs in a jungle QTH

A missionary friend of mine, home on leave from some jungle QTH, asked about tools, parts, and test equipment to take with him when he returns. His purpose: to keep his two SSB rigs operating. (One is a Kenwood TS-130 for Amateur operation, and the other's a six-channel, crystal-controlled portable HF SSB rig from Stoner Communications. The Stoner has been the mainstay of backpacking missionaries, but the new Yaesu portable is making inroads in that market). Although I have plenty of experience, including years of communications repair shop time and more than a few Beer Days . . . errr, I mean *Field* Days . . . I'm soliciting your help in this matter.

Why? Well, once upon a time a couple planning to spend a year on a desert island asked a physician — who had never been in such a situation — what medicines they should take with them. While they used few of the recommended medicines (except for aspirin), they regretted not having taken along a topical antibiotic for skin infections. If you've had any experience with repairing radio communications gear in remote areas, I would especially appreciate hearing from you.

references

1. R. Richardson, W4UCH, "Low-cost Spectrum Analyzer with Kilobuck Features," *ham radio*, September, 1986, page 82.

ham radio

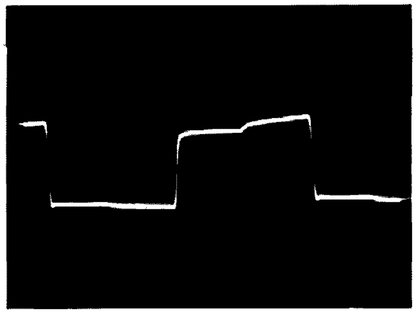


fig. 5A. Waveform seen on oscilloscope under typical load conditions: 50 ohms.

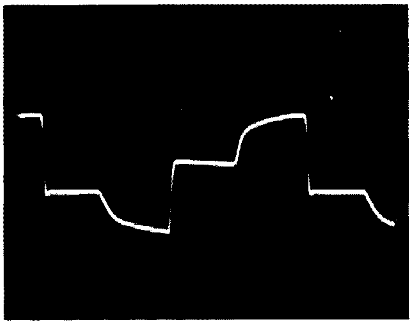


fig. 5B. Waveform seen on oscilloscope under typical load conditions: 22 ohms.

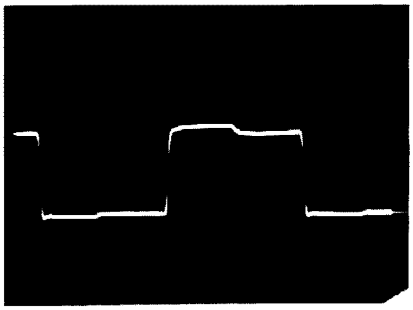


fig. 5C. Waveform seen on oscilloscope under typical load conditions: 75 ohms.

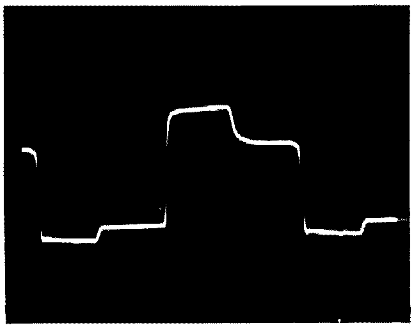


fig. 5D. Waveform seen on oscilloscope under typical load conditions: 150 ohms.

VHF/UHF WORLD

Joe Reisert W1JR

microwave portable operation

Spring and summer are the seasons of the year for VHF/UHF microwavers to dust off their rigs, fix all the gear that's been waiting for their attention, and get set to do some serious operating.

Portable operation offers some unique opportunities, especially if the home QTH isn't an ideal VHF location. Other reasons are often centered on the thrill of putting out rare VUCC grid squares, setting new DX records, or just the desire to commune with nature while enjoying our favorite activity. It presents some special problems however, not only for newcomers, but for old-timers as well. Often special equipment and antennas are required and things *can go* wrong — *even things* that might have been easily anticipated.

selecting your location

One of the first considerations in going portable is the choice of location. For starters, it probably would be advisable to select a location that's reasonably close to home. This will incur minimum expense, and if something goes wrong, you can either go home and bring back reinforcements or just QRT. After a few local operations, go for the long haul!

Successful portable or contest operation demands careful preparation. First, you'll have to determine whether the chosen location is accessible by conventional vehicles. Can you get there by four-wheel drive, or will you have to hike the last part of the trip? If you have to hike, what about lugging all the gear to the site? Is power available, or do you have to bring your own? (More on this shortly.)

Is the chosen location sufficiently clear so that you won't have problems erecting an antenna high enough to get above local obstructions — such as tall trees? It's always best to secure a topographic or geological survey map in advance. Usually available in local book stores, libraries, or sporting goods shops that carry camping or backpacking gear, such maps typically cover only a 7-1/2 minute section, 1/8 of a degree, or about a 6- by 9-mile area at midlatitudes. Therefore, more than one map may be necessary.

Accurate, detailed maps are invaluable, especially if you intend to operate near a state, county, or grid square border. You must always know, with a reasonable degree of certainty, *that you really are where you think you are!* Bring a camera; photos are good evidence, and you and your friends can enjoy the pictures for years to come (see **fig. 1**). They can also help when briefing others who may be interested in operating from the same location later on.

If possible, contact a local resident (preferably an Amateur) who's familiar with the area in question, or visit the proposed location before your operating excursion. Bring a small rig to try out the location. Check out possible operating positions, available facilities, and power sources. Don't underestimate travel and setup time! A preparatory visit will also give you a feel for the travel time from your home QTH so you can be on site and ready to operate at the scheduled time.

Even if you've visited the proposed location beforehand, bring a magnetic compass. Find the local magnetic offset for the proposed location before you leave home. In the New England area, the magnetic offset is over 15 degrees! If you have a distance and bearing program, this can be determined before you go.[1] Enter the approximate location for the magnetic north pole at 76 degrees north latitude and 101 degrees west longitude into your program.

An elementary knowledge of astronomy is also helpful for locating the North Star, but obviously this will be impossible in the daytime or if the

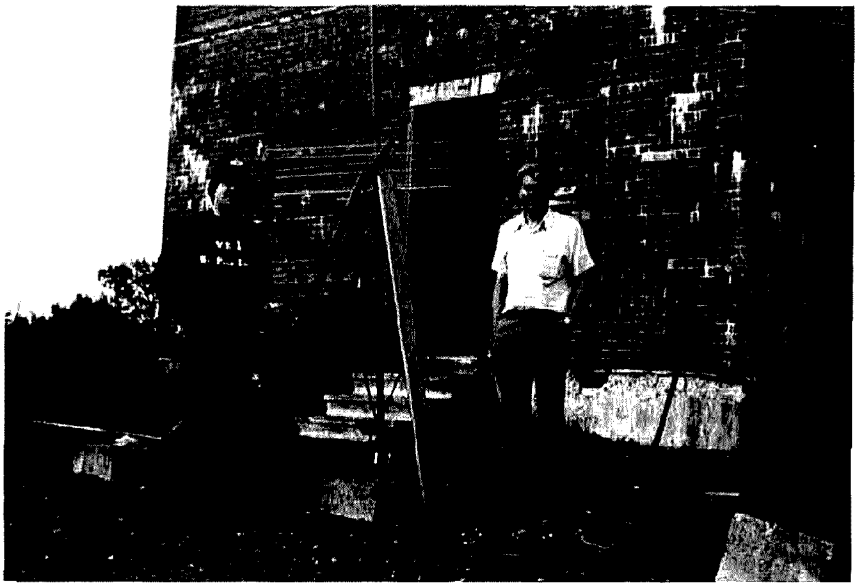


fig. 1. Antenna installation used by W1JR/CY1 operating from FN76 in the June, 1983 QSO party. The brick building was our shelter. Andy McLellan, VE1ASJ/VE1SPI is at left; Joe Reisert, W1JR is at the right.

Table 1. This table shows some of the more well-known mountain-top locations popularized by VHF/UHF/microwave and millimeter-wavers to set DX and contest records.

Name	Location (approx.)	Elevation (feet)	Grid Square
Eastern USA			
Cadillac Mountain	Bar Harbor, Maine	1,530	FN54
Mount Washington	Glen, New Hampshire	6,288	FN44
Pack Monadnock	Peterborough, New Hampshire	2,280	FN42
Mount Equinox	Manchester, Vermont	3,816	FN33
Mount Mansfield	Burlington, Vermont	4,393	FN34
Mount Greylock	North Adams, Massachusetts	3,491	FN32
High Point	Port Jervis, New York	1,803	FN21
Watchusett Mountain	Princeton, Massachusetts	2,006	FN42
Mount Mitchell	Asheville, North Carolina	6,684	EM85
Mount Toxaway	Oakland, North Carolina	4,777	EM85
Spruce Knob	Simoda, West Virginia	4,860	FM08
Western USA			
Pikes Peak	Colorado Springs, Colorado	14,110	DM78
Mount Rose	Reno, Nevada	10,778	DM09
Mount Diablo	Walnut Creek, California	3,849	CM97
Mount Hamilton	San Jose, California	4,209	CM97
Mount Pinos	Frazier Park, California	8,831	DM04
Mount Palomar	Julian, California	6,126	DM13
Mount Ashland	Ashland, Oregon	7,530	CN70

weather is inclement, so back to the compass! The local transit time of the sun can also be determined for a true south marker. Check maps ahead of time to see what azimuth directions will be used most. At the same time, check the approximate bearings of other local landmarks which can be used for additional sightings.

Probably the most famous VHF/UHF and microwave locations are the high hills and mountains where prior contesting has taken place or from which DX records have been set. Some of these are shown in **table 1**. Reference 2 discusses some of these locations and includes pointers on how to get to them and what to expect, as well as any particular local considerations. Regardless of the above, do your homework in advance, since it's often difficult to secure on-the-spot operating permission.

On-site rf emitters can be a problem. But they, too, can be checked on a preparatory visit. Elevated locations frequently have broadcast, VHF/UHF TV transmitters, repeaters, or other sources of local noise. Will this rf be a problem with spurious beats or noise? If so, choose another location or bring adequate external preselector filters with you just in case!

Portable contest operation involves several other considerations. Are you sure that when you arrive at the location, somebody else won't already be there? Always have a plan for a backup location! Are sleeping accommodations available, or must you provide your own? Is camping permitted? Do you need written or verbal permission to operate a transmitter or a generator at the location?

Can you *operate* at the chosen location overnight? Though overnight use of facilities is frequently not allowed at national or state parks, it can sometimes be negotiated before you go; try to get written verification before you go. Whatever you do, don't leave the local natives restless. And definitely — as the Boy Scouts say — always leave the area in the same shape or better than it was when you arrived. Remember, either you or some other Amateur may want to return.

establishing records

Record setting is surely one of the big reasons serious VHF/UHF and microwavers seek out portable locations. It's well known that the elevated locations will often add the extra low-angle takeoff so critical for record setting — not to mention the extended line-of-sight propagation on the upper microwave and millimeter-wave bands. Coastal locations are acceptable, especially if over-water paths are contemplated.

Some operational pitfalls deserve discussion. It's usually advisable to conduct some sort of rf liason, typically on 2 meters or 70 cm. Often, however, I've heard of disasters — especially if the path is long (over 20 miles or line-of-sight). For instance, if 2-meter fm is used for liason, will its signal be strong enough over the path?

Believe it or not, some operations have been unable to establish two-way 2-meter communications between high locations with a 10-watt fm rig operating into a quarter-wave car-mounted vertical antenna. In this case, even a small (three to four element) Yagi would have been sufficient to complete the path.

A Yagi antenna on a liason frequency has a second advantage. If it has high enough gain, it can be used as a crude direction finder so you'll at least know in what general direction other higher frequency antennas should be aimed! Typically, a ten-element or longer Yagi will have less than a 40-degree beamwidth — not as narrow as the typical record setting antenna, but definitely a confidence builder, especially if a visible sighting isn't possible.

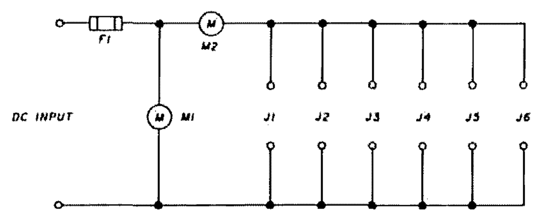


fig. 2. Recommended power distribution and monitoring circuit. M1 is a 0-25 volt dc meter. M2 is a dc ammeter, typically 10-20 amperes. F1 is the fuse, which is set by the current limit of the supply and/or ammeter. J1 through J6 are output terminals, as discussed in text.

choice of frequency and gear

Before you get too far along in your portable operation plans, the frequency and gear must be carefully selected. If single-band operation is chosen, the problems are considerably simplified. Do you have your own gear, or will you have to borrow some or all for the operation? Are you interested in just the more populated bands such as 6 and 2 meters, 70 cm (432 MHz) and 23 cm (1296 MHz)? Or do you want to go higher, or on one of the lower, less populated bands such as 135 cm (220 MHz) or 33 cm (903 MHz)? The more populated bands may yield more QSOs, but the less populated bands can often offer more satisfaction.

There's plenty of self-contained commercial gear available such as the "multimode" rigs that offer easy operation in a single compact package. Units manufactured by ICOM, Kenwood, and Yaesu — the most popular manufacturers — offer VHF/UHF coverage from 50 to 1300 MHz on CW, SSB, and fm. Some of these manufacturers even offer dual or multiband operation in the same package. Most of these rigs will operate on either 115 VAC or 12 to 13 volts dc.

Some operators prefer up/down converters or transverters, which can often be optimized for the ultimate in sensitivity, selectivity, and/or high dynamic range. References 3 through 10 provide typical circuitry for "rolling your own."

Many commercial manufacturers offer this type of gear from 50 MHz to 10.368 GHz! Popular suppliers are ARR, Microwave Modules, Mutek, and SSB Electronics. Remember that if an up/down converter is used, an extra hf transceiver or appropriate i-f will also be required.

power sources

It almost goes without saying that if commercial power is available at the proposed portable location, you're in luck. If not, there are several alternatives. Most low-power (less than about 100 watts) VHF/UHF gear will also operate on 12 to 13 volts dc. For short periods of time (i.e., a few hours), especially at lower power levels (100 watts maximum), the power can be taken from the battery in your automobile.

However, if this is done, extreme care must be taken. It's best to install a separate large diameter (No. 10 AWG minimum) wire connected directly to the battery terminals and kept to the minimum possible length to prevent large voltage drops. I'd also recommend that a circuit breaker or fuse be installed in this line as close as possible to the positive terminal of the battery.

Furthermore, I'd recommend that a power distribution and monitor box be fabricated. A schematic of a recommended type is shown in fig. 2. Note that it also has a fuse for double protection. The voltmeter is used to monitor the voltage regulation and warn of possible loss of battery charge. The ammeter monitors the current drawn by the gear in use. This will also aid in any troubleshooting exercise.

It's always wise to keep your automobile's gas tank as close to filled as possible. Be careful that you don't run the battery down too low, or you won't be able to start the car when your operation is completed! Start the car occasionally to let the battery recharge a little or bring along an extra charged battery just in case a backup is required.

Finally, the outputs of the power distribution box will give a flexible option for connecting and disconnecting units. I use the GR (General Radio) type of dual plugs on all equipment. GR plugs are specially marked for polarity, can carry heavy current with a minimum of voltage drop, and are very versatile and easy to install. They're also compatible with most dc power supplies.

If you're using a small antenna rotator, it may be wise to have a low-power 115-VAC source. I'm told that Radio Shack has a small 12-volt dc to 115-VAC power inverter that's just fine for this application. However, I'd be wary of using this type of inverter on a regular transceiver because the voltage waveform may not be sinusoidal and could cause voltages to be higher or lower than expected.

If all else fails, or if higher power is desired, a gasoline-powered generator may be advisable. These can be rented, but they're also quite affordable nowadays and may represent a prudent investment if you plan many portable operations. (Such a purchase can be simplified by first convincing your spouse of its unquestionable value as a source of electricity during power failures!)

AC generators are sold in many types and power ratings. Always choose one that has at least a 25- to 50-percent power reserve. Generators can be temperamental, so a few pointers are in order. Using a generator near its normal maximum load can cause instabilities and other erratic operation. Always test yours out before your trip to verify its reliability. Bring plenty of extra gasoline, spare spark plugs, and extra oil (if oil is required).

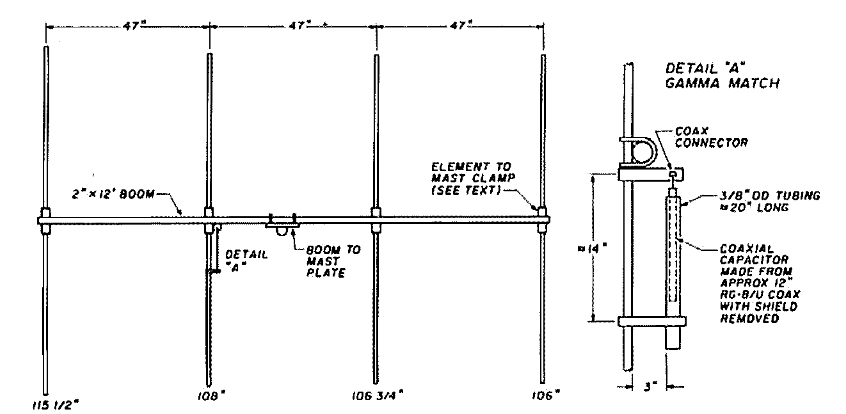


fig. 3. Construction details for the simple four-element, 6-meter Yagi described and recommended in the text. Element diameters are 1/2 to 3/4 inches. (See text and reference 13.)

portable antennas

Next to the selection of your location, the most important key to success is your antenna. While you're not likely to be running high power, every bit of antenna gain will be important to attract attention. You'll probably hear all the more powerful home stations. But will they be able to hear you?

There are many factors to consider in choosing a portable antenna. Unless you're going to operate on just one band, a moderate-sized Yagi would almost certainly be your best choice. Although a large antenna would obviously be hard to aim and keep aloft, especially if you're operating alone, your antenna should be as long as conveniently manageable, since the apparent path attenuation increases with frequency unless the physical aperture of the antenna is the same.[11]

I've seen poor results on 70 cm when a portable station took down a 20-foot boom, 2-meter Yagi and replaced it with a 10-foot boom, 70-cm antenna. Try using the same boom-length antennas on each band. Your performance on the higher bands will be either the same or improved.

Some operators prefer to change antennas each time they change bands; if you do this, you can use a larger antenna on each band. Others may operate two or three bands, but prefer to mount all antennas on a single mast. In this case, the size of the individual antennas will probably have to be smaller. The choice is really one of convenience versus performance.

Another antenna constraint is transportation. If you have roof racks, you may be able to support a fully assembled 12- to 15-foot boom Yagi. If the antennas are transported inside a car or in a car trunk, they may have to be limited in size or broken down into shorter lengths not exceeding 5 to 8 feet. In the latter case, it may be possible to design the boom so that it can be conveniently broken down into shorter sections.

Try using Yagis that are easily assembled and preferably symmetrical. Most, but not all, Yagi designs use either similar length or a downward director taper. These designs are preferred for portable operation since there's less likelihood of positioning the directors on the boom incorrectly. Mounting and assembly are also simplified.

If beams are broken down for transporting, place electrical tape or its equivalent on the elements or boom before transporting to mark the proper location of elements for reassembly. Steve Murray, K1KEC, taught me another trick: when transporting antennas, always tape down any loose nuts so they won't shake off and get lost.

✓ 114

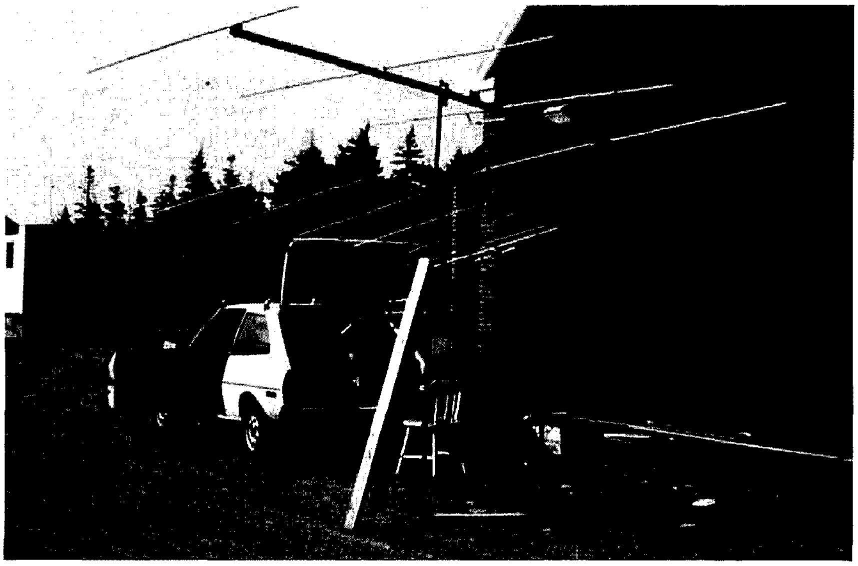


fig. 4. Portable operation by W1JR/1 in FN54 in the June, 1983 ARRL QSO party. Operation is from the car's tailgate. Notice the tripod as detailed in fig. 5. The antenna on the bottom is the eight-element, 2-meter Yagi described in reference 13. The antenna on the top is the four-element, 6-meter Yagi shown in fig. 3.

Finally, just in case you do lose some hardware during transportation, bring along a few spare nuts, bolts, and screws in your tool box. You'll never regret it.

For 6-meter operation I prefer a 12-foot boom Yagi. This is a convenient length for a four-element design. I also prefer a 1-3/4 to 2-inch diameter boom so that the elements won't spin. A single piece of tubing can be used, but you may prefer to use a two-piece boom with a center joining section. WD4BUM* can provide a suitable boom with 6-foot sections.

My 6-meter antenna follows a symmetrical design with equal element spacing and is based on an unpublished 0.6-wavelength NBS design.[12] It offers gain of just under 10 dBi, and — along with other VHFers in the W1/VE1 area — I've used it extensively to put out rare grid squares. It's also been used to work not only the USA and Canada, but Europe, the Caribbean and South America, all with low power!

The mechanical details for this design are illustrated in **fig. 3**. The finished product is shown in **fig. 4**. My antenna was built from an old CB antenna, but parts from an old 6- or 10-meter beam are sufficient. The construction techniques are similar to those described in last month's column.[13] The elements can be any diameter between 1/2 and 3/4 inches or tapered (as discussed in reference 13). A gamma match is used because it's small and easy to fabricate. You may have to adjust the length of the driven element, the length of the coaxial capacitor, or the shorting bar slightly for optimum VSWR.

Many small 6-meter or "hilltopper" Yagis are available commercially. For 2 meters, there are also many choices: if you're a homebrew artist like myself, the eight-element Yagi design described in last month's column is highly recommended.[13] It has a great pattern, about 13.5 dBi of gain, and fits on a 12-foot boom. What could be simpler?

Many NBS Yagi designs are also described in reference 12. The 0.8-, 1.2-, and 2.2-wavelength designs are particularly recommended for 2 meters because they offer manageable lengths and reasonably good gain and radiation patterns. Likewise, there are plenty of commercial 2-meter Yagis available in many different boomlengths and prices. Some are even specifically designed for mountaintopping.

Stan Jaffin, WB3BGU, originally became interested in 2-meter antennas suitable for mountain-topping. He therefore devised Yagi analysis programs which later resulted in several articles on optimized 50- through 450-MHz Yagi designs.[14] His articles discuss a number of optimized designs in this frequency range.

Stan offers a few suggestions for 2-meter portable antennas. Yagis measuring 72 inches are suitable for carrying in an automobile, but 50-inch booms are good if you want to transport your antenna in your trunk, where it's out of sight. Stan also prefers wooden booms at least 3/4 inch wide, since wooden boom antennas don't require boom corrections and work fine as long as they're not exposed to the elements for extended periods of time. Stan also feels that the elements should be substantial enough (at least 3/16 inch diameter) so that the elements don't break or bend during transportation or in the wind.

Designs for 135-cm Yagis are available in references 12 and 14. The NBS 4.2-wavelength design is particularly recommended if a 19-foot boom is used. Several commercial 135-cm Yagi designs are also on the market.

Many 70-cm Yagi designs are readily available. The NBS Yagi designs allow choices of up to 4.2-wavelength booms.[12] The DL6WU Yagi designs can be used for boomlengths of 2 or more than 10 wavelengths.[15] On several expeditions I used the 24-foot boom Yagi design described in last December's column.[16] The K2RIW 19-element and the new K1FO 22-element Yagi designs are excellent for 13- to 14-foot boomlengths.[17] Kits of parts for the W1JR, K1FO, and K2RIW designs are now available from Tom Rutland, K3IPW**. Many commercial 70-cm Yagis are also available.

* George Shira, WD4BUM, Route 7, Box 258, Anderson, South Carolina 29624.

** Tom Rutland, K3IPW, 1703 Warren Street, New Cumberland, Pennsylvania 17070.

*** Down East Microwave, W3HQT, Box 1655A, RFD 1, Burnham, Maine 04922.

The loop Yagi, surely one of the most popular antennas on 23 and 33 cm, can be built on a 12-foot boom. Gain is high and the size is quite manageable. Details on loop Yagi design can be found in references 9, 10, and 18. Loop Yagis are available from Down East Microwave.*** Several other sources manufacture Yagis for both bands.

Fewer antennas are available for 13 cm (2304 MHz) and above. The 45-element loop Yagi is a good choice.[18,19] Down East Microwave*** offers this loop Yagi.

Parabolic dishes are also popular on 13 cm and above. However, if solid dishes are used, they may require a good mount because windload can be severe. Smaller dishes (18 to 24 inches in diameter) are often used on 3 cm (10 GHz) and can often be mounted on a good tripod similar to those used by surveyors. This also will allow some degree of azimuth calibration if a compass rose is available on the tripod mounting. Design of parabolic dishes and feeds for 13 cm and above are discussed in references 20 and 21.

towers and masts

By now it should be obvious that the type and size antenna used in portable operation is determined largely by the way it's supported. Several methods in widespread use include towers, tripods, and masts. Regular towers are great, but they're usually bulky and require guys and possibly special mounting techniques such as attachments to the side of a camper.

Some Amateurs prefer to use just a simple mast mounting. They usually attach some sort of pipe fitting near the end of a large plank and fit a 10- to 15-foot mast into the pipe flange. If the plank is large enough and the flange is near one end, it can be supported by driving over the top of the end with one wheel of an automobile. The support can consist of multiple sections of the 5-foot TV type masts that are readily available at Radio Shack and suppliers of TV antenna accessories.

There's at least one technical

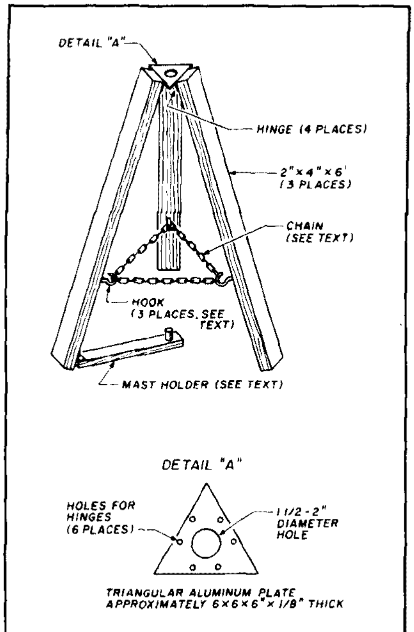


fig. 5. This figure shows details of a homebrew tripod suitable for portable operation (see text).

problem with this mounting method. An antenna mounted near an automobile may suffer pattern distortion. The larger the antenna and the closer to an automobile, the greater the problem. As a rule of thumb, antennas should be spaced at least 25 to 50 percent of their boomlength away from any local objects. This is particularly important for those who use masts or towers attached to a camper. Furthermore, antennas should always be mounted at least 1 to 2 wavelengths above the ground for tropo work or at least 7 to 14 feet high on 2 meters.

I prefer tripods or small self-supporting towers for portable operation. Several manufacturers now supply four-legged free-standing towers. I use the one shown in **fig. 4** of last month's column[13] on my portable EME station. These small towers usually have hooks at the top to *allow guy lines* to be added if necessary.

Figure 5 shows construction details for a simple tripod that I use for portable operation and back yard antenna testing. It consists of three 6-foot lengths of 2 X 4 lumber joined at the top to a triangular aluminum plate using small hinges available in hardware stores. A hole large enough to pass a mast through is drilled in the plate. An inexpensive piece of chain link is used to hold the shape and it is attached between the legs with hook eyes.

This tripod (**figs. 1** and **4**) is relatively compact, and the weight of the lumber makes it very stable even in a mild wind. The antenna mast can be sections of the 5-foot TV type just described, which can rest on the ground. For a more substantial mast holding method, I sometimes use a plank such as the one described above, which can be attached with another hinge to one of the tripod legs (see **figs. 1** and **4**). For peace of mind, I sometimes attach a rope to the antenna in use to hold it in position, but I'm sure there are better safety methods.

Amateurs who go portable devise many different ways to hold their antennas. Antenna rotators can be used, but will require 115 VAC, as discussed earlier. Others attach a lever arm to the mast to allow quick steering. Whatever method you use, do consider something that will allow a relatively accurate azimuth indication such as a compass rose, since this may mean the difference between success and failure of your operation.

transmission lines and VSWR indicators

One big advantage of portable operation is that transmission lines are usually short. Hence, lower cost coax such as RG 8/U or RG 213/U may be perfectly acceptable. The newer 9913 coax is especially recommended if you want very low loss or expect to work on 70 cm and above.

Because you sometimes don't know how long a feedline will be required at the site, I prefer to take several short cables as well as a few 10- and 25-foot feedlines, all fitted with type-N connectors. If the first feedline is too short just add another section, joining them with a coax barrel adapter.

Another suggestion: if you keep the number of connector types to a minimum, you won't have to bring too

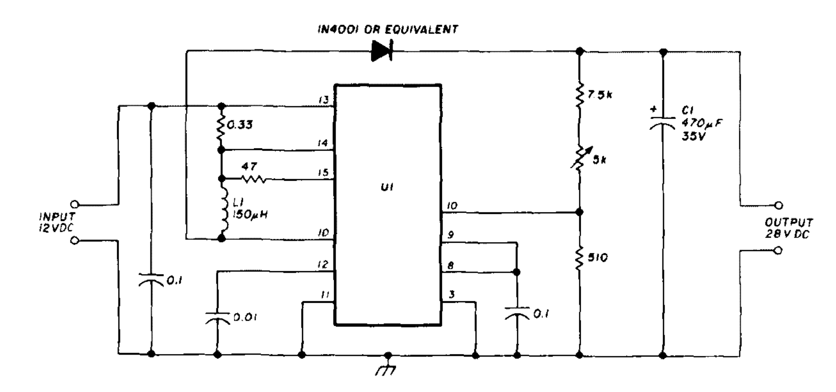


fig. 6. Switching regulator capable of operating with a 12-volt input and providing a nominal 28-volt output sufficient to drive a typical 28-volt t/r relay. U1 is a Fairchild 78S40 IC and L1 is a 150 μH high-current inductor.

many different types of adapters. I prefer to use either type-N or BNC connectors in portable operation. Furthermore, bring along several short coax cables with the correct type of connectors so you can easily bypass rigs in case of unexpected equipment failure.

One indispensible accessory is a VSWR/power meter. Don't leave home without it! Not only will it tell you that your transmitter is putting out the correct power, but it will give you a quick indication of VSWR that may tell you if the antenna system is functioning properly. This is particularly important on portable operation because the antenna may have been improperly assembled in a hurry to get on the air. If only a VSWR meter is used, try to have it calibrated before leaving home so that you'll at least be able to know that the power indicated is in the ballpark.

antenna relays

Most of the popular multimode transceivers have built-in t/r relays. However, if an external preamplifier or power amplifier is used, an additional t/r relay may be necessary. Since most portable operation requires a 12-volt dc relay, you should obtain one well ahead of time and check it out, especially with respect to integration with the t/r switching. I may be old-fashioned, but I use a footswitch on all operation because I feel it's more reliable and allows me other freedoms. I have a small box with the switching and voltages all wired beforehand.

If you can't find a 12-VDC t/r relay you can use the 28-volt type, which is more readily available. But how do you use it on 12 volts? The answer is that you need an external 24- to 28-volt supply that's powered from 12 VDC.

Figure 6 shows a schematic of such a supply which will operate on 12 to 13 VDC and deliver a nominal 28 VDC. It uses one of the newer IC chips and will easily provide enough current to drive a single 26-volt t/r relay. This circuit works as a "switching regulator." Such a device is really an oscillator that operates very efficiently in supplying power to the output filter capacitor, C1, on demand. Normally the internal diode between pins 2 and 1 of the IC is used to connect to the output filter/divider. However, I used an external diode to keep chip dissipation to a minimum. One caution: switching regulators generates rf spikes. Therefore, it's best to place the circuit in a shielded box and filter the dc input and output lines.

The circuit shown in **fig. 6** is quite straightforward. The only special components are the IC chip (a Fairchild 78S40) and the switching inductor. The inductor should be of the very high current type made with large gauge wire such as the J. W. Miller type 5506 or equivalent. If you can't locate these parts, Circuit Cellar offers a package deal of the 78S40 and the Miller inductor for $15.00.****

Recently a new series of switching regulator chips with higher output current capabilities was introduced by Linear Technology Corporation. Several choices such as the LT1070CK, LT1071CK, and LT1072CK, with specified output currents of 5, 2.5 and 1.25 amperes, respectively, are offered.

I built the circuit in **fig. 7** using the higher current device, the LT1070CK, which costs $12.74 in small quantities and the same inductor as used in **fig. 6**. I haven't completely put this circuit through its paces, but it looks as if it will have considerably more output current capability than the 78S40 circuit. Therefore, if high current isn't required, you may want to use one of the lower-cost chips in this series.

power amplifiers

So far I haven't mentioned power amplifiers. They aren't always needed for portable operation. However, there are many choices if solid-state amplifiers are used. Reference 7 describes circuitry that will work for solid-state power up to the 100-watt level through 70 cm. Many different solid-state amplifiers are available commercially.

If you really want to go high power, tubes are still king. However, you'll probably need to use either local power or bring along a generator so that the filament and high voltages can be generated conveniently.

A couple of years back there were some AM6154 and AM6155 tube-type power amplifiers on the surplus market. They can be adapted to operation on 144, 220, and 432 MHz.[22] This amplifier seems like just the ticket for high-power portable operation because it's relatively small, fully self-contained, and can deliver 300 to 500 watts of rf with 10 to 20 watts of drive.

field repairs

Because it can be very frustrating working in the field, especially if a

**** Circuit Cellar, P.O. Box 428, Tolland, Connecticut 06084.

Table 2. Items recommended for a trouble-free portable operation. This list is by *no* means complete; you may want to expand some categories as you make your own list.

Antennas, transmission lines, and accessories:
antennas
tripod/tower
rotator
feedlines — short, medium and long
link antennas
masts
rope
coax cable adapters

Equipment:
radios
link gear
HT
t/r relay and power source
straight key and keyer
spare fuses
spare preamplifiers
power amplifiers
master control system
preselector filters
earphones
power distribution box (**fig. 2**)

Power generation:
ac generator (plus spare plugs, gasoline, oil)
dc to ac inverter
batteries
extension cords and ac outlet strips
power supplies (if required)

Tools and supplies:
tools (make a long list)
hookup wire
hardware
pipe cleaners
soldering iron and solder
electrical tape
ruler/tape measure
clip leads

Test equipment:
multimeter
noise generator
power/VSWR meter
frequency calibration source

Miscellaneous:
compass
pens, pencils, scratch paper
folding table
operating platform
beverage cooler stocked with water
manuals on gear being used
camera and film
logbooks
tent/tarpaulin
folding chairs
first-aid kit, aspirin, insect repellent
beverages and snacks
lamps/flashlight
maps

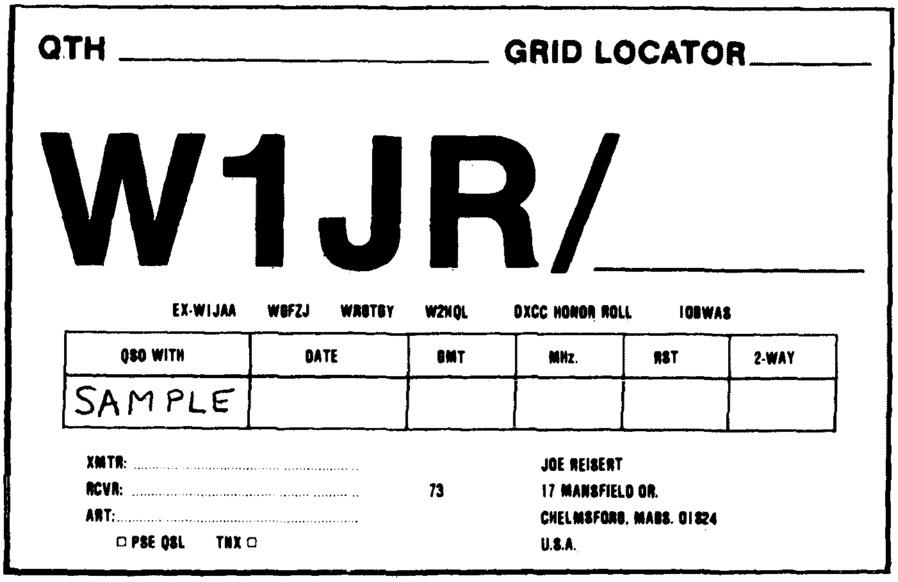


fig. 8. QSL card used by W1JR for portable operations.

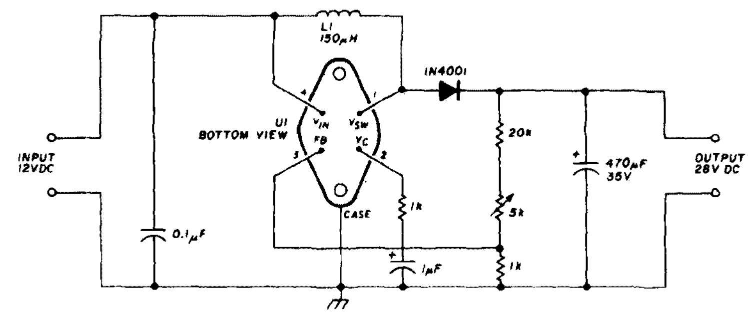


fig. 7. Circuit for a higher power switching regulator. U1 is a LT1070CK and L1 is the same as in fig. 6. Provide a good heatsink for the IC, which is a TO-3 package. Keep grounds and returns around the IC as short as possible.

failure occurs, always bring along extra gear, tools, and supplies. A multimeter is a *must*. Many inexpensive hendheld types are available. A crystal calibrator is also nice for checking if you're on frequency.[23] I also carry a simple noise generator made with a diode, battery, and coax attenuator. It isn't accurate, but it can tell you in one quick test if your preamplifier or receiver is inoperative!

It's also a good idea to bring along a soldering iron. On one expedition I needed one to repair a broken relay coil. Luckily I was able to borrow a battery-operated one locally, and it saved the day! At the same time I needed a light. I had a flashlight, but I was alone and didn't have three hands. I recommend a lamp that operates from a car cigarette lighter. It can also help by providing light for filling out your log.

If you're working on 115 VAC, don't forget to bring extension cords and extra power outlet strips. Extra leads with alligator clips are great for makeshift patching. I also recommend that you carry a package of ordinary pipe cleaners. They're great for removing water or other debris that can get into coax connectors.

amenities

I really haven't discussed creature comforts. If you're going to operate from a car, bring along a board or platform on which to mount your rig, key, and logbook. If your car has a tailgate you can set the gear on it, but don't forget to bring a folding chair. Of course, campers or vans can be ideal for portable operation since they usually have a built-in table and seat.

If you're not fortunate enough to obtain the use of a local building, bring along a tent or tarpaulin to not only help in inclement weather, but shield you and your gear from the high temperatures of direct sunlight.

Table 2 lists these and other items necessary (or advisable) for a successful portable operation. This list may not be complete. Suggestions and information on mountain-topping from another perspective is also available in reference 24.

If you decide on portable operation, first generate your own list and check off each item before you go out into the field. Even better yet, set your entire station up in your back yard or driveway and try it out. When all is working to your satisfaction, review your checklist and pack everything in sight into your car!

the final courtesy

Once you've completed operation from that special location, go home, unpack, and wait for the mailman to arrive with all the QSL requests! Yes, that's what it's all about. Just think of all those VHF/UHFers who struggled to work you for a new state, grid, or DX record!

It's really not hard to confirm a QSO, but many portable operations want to send out special QSLs or some great memento. This could take many months and cost plenty, especially if photographic QSL cards are desired. Special QSLs are fine, but the ham waiting for the card couldn't care less. (Don't forget all the phone calls and duplicate letters asking whether you received the QSLs and why you haven't QSLed yet.)

One quick way to QSL is to just mark up one of your own regular station cards or fill out one of those often offered as an advertising gimmick. But why not make up a universal QSL card instead — especially if you contemplate multiple operations or multiple QTHs?

With the help of Steve Gilbert, WA1AYS, who has his own printing business, I've done just that. It's simple and effective, and it does the trick with a minimum of work and expense. The final result is shown in **fig. 8**. All you have to do is to fill in the QTH and grid square along with the usual information. Think about it the next time you're planning a trip; it certainly simplifies QSLing.

summary

Portable operation on the VHF/UHF, microwave, and millimeter-wave bands is becoming quite a popular sport. I've tried to provide suggestions on how to improve your success rate; obviously, the most successful operations are those that were planned, tested, and integrated at home instead of on location.

acknowledgments

I'd particularly like to thank those who suggested a column on this subject, and especially Stan Jaffin, WB3BGU, for his helpful suggestions about antennas.

Important VHF/UHF Events

June 7	*Predicted peak of the daytime Arietids meteor shower at 1900 UTC.*
June 10	*Predicted peak of the Zeta Perseids meteor shower at 0400 UTC.*
June 13	*EME perigee.*
June 13-15	*ARRL June VHF QSO party.*
June 20-21	*SMIRK Party Contest (contact KA0NNO).*
June 21	*Peak of sporadic-E propagation (± 1 month).*
July 1	*Look for European 6-meter opening (± 1 month).*
July 11	*EME perigee.*
July 18-19	*CQ Magazine VHF WPX Contest.*
July 20	*Look for 2-meter sporadic-E propagation (± 2 weeks).*
July 23-26	*Central States VHF Conference, Arlington, Texas (contact KD5RO).*
July 29	*Predicted peak of the Delta Aquarids meteor shower at 1500 UTC.*

references

1. RF CAD Package — Version 3.51, Computer-aided design package for radio frequency and microwave circuits and antennas (IBM PC compatibles), developed by Joe Reiset, W1JR, and Gary Field, WA1GRC. Available from Ham Radio's Bookstore, Greenville, New Hampshire 03048 for $39.95 plus $3.50 shipping and handling.
2. Wayne Overbeck, N6NB, "VHF Mountain-topping in America: A Travel Guide," *QST*, July, 1980, page 46.
3. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Receivers," *ham radio*, March, 1984, page 46.
4. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Exciters," *ham radio*, April, 1984, page 84.
5. Joe Reisert, W1JR, "VHF/UHF World: High Dynamic Range Receivers," *ham radio*, November, 1984, page 96.
6. Joe Reisert, W1JR, "VHF/UHF World: Low-Noise GaAsFET Technology," *ham radio*, December, 1984, page 99.
7. Joe Reisert, W1JR, "VHF/UHF World: Medium-power Amplifiers," *ham radio*, August, 1985, page 39.
8. Joe Reisert, W1JR, "VHF/UHF World: High Dynamic Range on 2 Meters," *ham radio*, November, 1985, page 54.
9. Joe Reisert, W1JR, "VHF/UHF World: 33 cm — Our Newest Band," *ham radio*, April, 1986, page 83.
10. Joe Reisert, W1JR, "VHF/UHF World: 33 cm Update," *ham radio*, April, 1987, page 74.
11. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-Wave Propagation — Part 1," *ham radio*, July, 1986, page 82.
12. Joseph H. Reisert, Jr., W1JR, "How to Design Yagi Antennas," *ham radio*, August, 1977, page 22.
13. Joe Reisert, W1JR, "VHF/UHF World: Optimized 2- and 6-Meter Yagis," *ham radio*, May, 1987, page 92.
14. Stanley Jaffin, WB3BGU, "Applied Yagi Antenna Design, Parts 1-6," *ham radio*, May through October, 1984.
15. Günter Hoch, DL6WU, "Extremely Long Yagi Designs," *VHF Communications*, Fall 1982 issue, page 130.
16. Joe Reisert, W1JR, "VHF/UHF World: A High-gain 70-cm Yagi," *ham radio*, December, 1986, page 75.
17. Steve Powlishen, K1FO, "The K1FO 22-Element, 432-MHz Yagi," *VHF/UHF and Above*, January, 1987, page 2.
18. Joe Reisert, W1JR, "VHF/UHF World: Designing Loop Yagis," *ham radio*, September, 1985, page 56.
19. Joe Reisert, W1JR, "Designing Loop Yagis for 13 And 23 cm," *Proceedings of the First 1296/2304 Conference*, Estes Park, Colorado, September, 1985.
20. Joe Reisert, W1JR, "VHF/UHF World: Reflector Antennas — Part 1," *ham radio*, February, 1986, page 51.
21. Joe Reisert, W1JR, "VHF/UHF World: Reflector Antennas — Part 2," *ham radio*, March, 1986, page 68.
22. Joe Reisert, W1JR, "VHF/VHF World: High Power Amplifiers — Part 2," *ham radio*, February, 1985, page 38.
23. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Frequency Calibrator," *ham radio*, October, 1984, page 55.
24. John Lindholm, W1XX, "VHF Mountain-topping for the '80s," *QST*, March, 1986, page 49.

ham radio

test DBMs for diode leakage

Decreased performance indicates damaged diodes

Commercially manufactured diode double-balanced mixers (DBMs) are popular with experimenters and equipment designers because of their low cost, predictable performance, and versatility. They're used as mixers, all kinds of modulators, and current-controlled attenuators.

But mixers can suffer from failure that degrades performance without catastrophic destruction. This damage, caused by transient inputs exceeding ratings, may go unnoticed unless mixer performance characteristics are specifically tested.

It's important to be aware of this effect when using an old mixer in a new design, or when performance seems to decrease. This article provides a method for making quick functional checks of mixer performance that can prevent a lot of frustrating troubleshooting.

mixer abuse

The obvious solution to the problem raised in the previous paragraph is to not exceed the manufacturer's specifications. However, we're all experimenters and tinkerers — and we just might install a mixer in a new configuration, inadvertently causing problems that aren't immediately apparent. We might use the same damaged mixer in a number of different projects, with disappointing, seemingly inexplicable results. And we *are* known for trying to squeeze maximum performance from a component by exceeding its ratings.

Mixers can be used in several different applications. A DBM makes a very simple and trouble-free balanced modulator for generating a DSB signal. The DBM doesn't require external adjustment of balance controls, and since these controls aren't used, it doesn't require subsequent readjustment to compensate for drift. The DBM balanced modulator is connected as shown in **fig. 1**. I used this scheme to generate a DSB signal using an LM386 IC audio amplifier driving the DBM i-f port. This worked perfectly, and its simplicity made it seem ideal. However, carrier suppression deteriorated after a period of use, and was cured by replacing the DBM. I was confused; a quick ohmmeter check on the mixer diodes indicated that they were still intact. The DBM had to be soldered into the circuit to determine that its balance had changed.

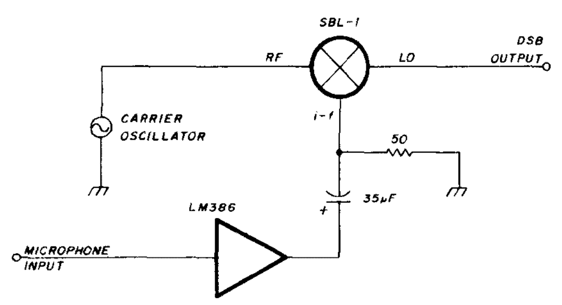


fig. 1. Balanced modulator using SBL-1 dBm.

But how was the DBM damaged? **Figure 2** shows the schematic of a Mini-Circuits SBL-1 mixer with the equivalent circuit for dc representation of the diodes. There is direct access to the diodes through the i-f port, making them most vulnerable to damage when the i-f is used as an input, which often occurs where a low frequency rf input is required but only a high frequency DBM is available. The LM386 power amplifier could easily generate transients that exceeded the DBM's 40 mA maximum i-f current rating. These glitches only happened when making connections or touching the amplifier input leads. Normal microphone input resulted in *normal* modulation.

testing

Checking the damaged mixers with an ohmmeter didn't seem to reveal much difference between a bad and a good mixer. Continuity checks are done to test for typical semiconductor failures — opens and shorts. The resistance measurements shown in **table 1** were carefully made to document results. I used a Micronta 22-204A meter; other meters will provide different but similar results. Study of the actual resistance measurements reveals that mixer damage tends to progressively deteriorate the diode reverse leakage and cause imbalance. A good mixer has higher (and equal) reverse resistances than a damaged mixer. Continuing to operate with additional mixer damage causes the reverse resistance to decrease. When it reaches 20 or 15 ohms per diode, the DBM will pass virtually no signal.

I knew that I was in big trouble because I had a collection of used DBMs that might or might not have been damaged. The familiar balanced modulator

Cliff Klinert, WB6BIH, 1126 Division Street, National City, California 92050

Table 1. Mixer test data.

Resistance on Pins:	Bad Mixer 1 Forward	Bad Mixer 1 Reverse Ω	Bad Mixer 2 Forward	Bad Mixer 2 Reverse Ω	Good Mixer Forward	Good Mixer Reverse Ω
3-5	7.0	35	8.0	42	7.5	45
5-4	7.0	30	7.5	34	7.5	45
4-6	7.5	35	8.0	45	7.5	45
6-3	7.5	35	8.0	33	7.5	45
Isolation R-L at 10 MHz	15 dB		20 dB		Unmeasurable (>>30 dB)	
Loss 10 mA i-f current	10 dB		7 dB		3 dB	

Note: Check ohmmeter current before making resistance measurements. To prevent damage, current into a diode shouldn't exceed about 40 mA.

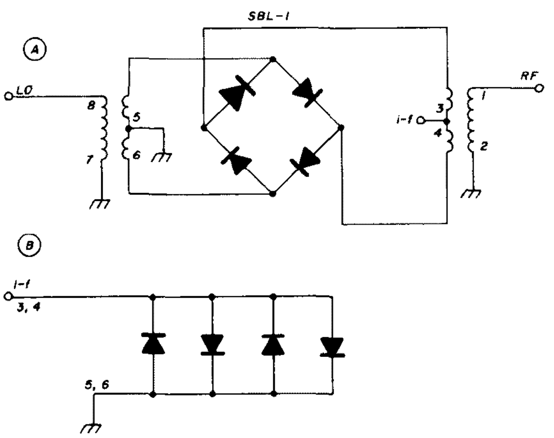


fig. 2. Double balanced: (A) mixer schematic, (B) dc equivalent circuit.

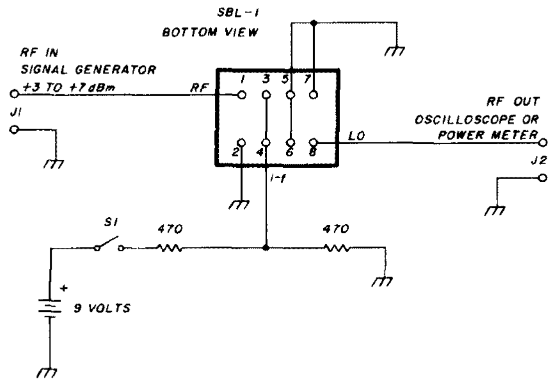


fig. 3. Mixer test fixture using more than 0 dBm input ensures that the mixer diodes have adequate drive power.

seemed like a good basis for a test fixture, so I settled on the circuit shown in **fig. 3**. Constructed on a perforated board, this circuit was used to prepare the rf measurements listed in **table 1**.

Mixer sockets aren't available, so I made one by cutting up some IC sockets. This approach wasn't entirely successful because the pin sizes don't match. Crystal sockets have the same problem, so it may not be practical to build a permanent test jig. Applying 10 to 20 mA of current to a DBM i-f port will reduce rf-LO isolation to 3 dB or less. The resistors shown in **fig. 3** terminate the i-f port with about 50 (specifically, 47) ohms, and the 9-volt battery supplies about 10 mA of i-f current. Press S1 to make the **table 1** loss measurements. J1 and J2 can be reversed with similar results. This mixer output should be terminated with a 50-ohm load for precise results, but even a high input impedance oscilloscope is adequate to differentiate between good and bad mixers. A receiver with a calibrated variable attenuator could perhaps be used to measure a good mixer's typical 50-dB isolation accurately.

summary

I was amazed to find a semiconductor failure mode resulting in gradual damage rather than complete instant destruction. It's necessary to make a careful check of mixer diode resistances, or a quick rf test to identify this problem. Precise measurements could be made, but aren't necessary for functional testing.

bibliography

RF/IF Signal Processing Handbook, Volume 1, Section 2, Mini-Circuits Labs, P.O. Box 166, Brooklyn, New York 11235.

ham radio

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

R-390A RECEIVER: $195 check; $115 reparable. Parts, tubes, sections. Info SASE. Mint military-spec pull-out 12AT7, 6AG5: $15/dozen. CPRC-26 six meter transceiver (see Ham Radio, March 1985) $17.50 apiece, $32.50 pair (add $4.50/unit shipping). Baytronics, Box 591, Sandusky, OH 44870. (419) 627-0460 evenings.

DUAL ANTENNA Rotor Controller. For info SASE to: A & A ENGINEERING, 2521 W. La Palma Ave, #K, Anaheim, CA 92801. (714) 952-2114.

SELL MFJ-1270 TNC2. New in box. Will UPS for $100.00. Matt (512) 675-3323 or Callbook QTH.

SUPERFAST MORSE CODE Supereasy. Subliminal cassette. $10. Amazing mnemonics: Learn Morse Code in 1 hour; Q signals supereasy; Novice written exam supereasy! $5 each. Moneyback guarantee. Free catalog. SASE. Bahr, 2549-H2 Temple, Palmbay, FL 32905.

TEST EQUIPMENT: HP8551B/851B Spectrum Analyzer and display section, frequency range 10.1 MHz to 12 GHz sensitivity up to -100 DBM $1,650.00, measurements model 800 FM signal generator, covers FM bands 25 MHz to 960 MHz $550.00. HP606A signal generator 50 kHz thru 65 MHz $375.00, HP803A VHF impedance bridge 50 MHz thru 500 MHz, 2 to 2000 Ohms, measures directly, plus phase angle $125.00, HP616B microwave signal generator 3.8 GHz thru 7.6 GHz $375.00, URM-25D signal generator 10 kHz thru 50 MHz $245.00, HP414A autovoltmeter $85.00, URM-32A frequency meter 125 kHz thru 1000 MHz $59.50. Lab calibrated, satisfaction guaranteed, Visa, M/C or check, add shipping, phone Bill Slep (704) 524-7519. SLEP ELECTRONICS COMPANY, Highway 441, Otto, NC 28763.

MORSE CODE TUTOR 5-35 wpm. IBMpc compatibles. Random characters, disk file, variable speaker frequency. $7.00 plus $2.00 S&H. Jack Goral, N9ERY, 105-60th Street, Downers Grove, IL 60516.

BACK ISSUES of HR Magazine from Vol. 1 No. 1 thru 1986, except 2 issues. $200 for all, postpaid. Also PopTronics, RE, 73 back to 1961. $20.00/full year. Write with your needs. Bill Fossman, 632 Wetmore, Everett, WA 98201.

ANALOG AND RF CONSULTING for the San Francisco Bay area. James Long, Ph.D N6YB (408) 733-8329.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

IBM/APPLE COMPUTER program "Hamlog". 18 modules logs auto-sorts 7-band WAS/DXCC. Full feature. Also CP/M. Apple $19.95, IBM $24.95. HR-KA1AWH, PB 2015, Peabody, MA 01960.

IBM-PC SOFTWARE: CW Keyer, COM sends CW from RS232 port, any speed, using type ahead buffer, memory or disk. $29.50. ELEC. EXE solves most common electronic equations, $19.50. Bill Feldmann, 6677 Charing St. Simi, Calif. 93063, or SASE for details.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521-5280.

WANTED: EIMAC 8873 tube for Heath SB-230. Please contact G2DRT, F.S.G. Rose, 84 Cock Lane, High Wycombe, Bucks HP 13 7 EA England.

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252.

NJ-NJ-NJ-NJ-NJ-NJ-NJ-NJ A Full-Service Ham-SWL-CB-Scanner store in NJ. Discount Grand Opening Prices. Top performing radio systems for every budget. New 10 meter and VHF/UHF rigs. ARRL, Amphenol, Astatic, Astron, Azden, B&W, Bilal Belden 9913, Butternut, Clear Channel, KLM, Larsen, MFJ, Mirage, Mil Spec Cables, much more. Open M-F 10 AM-9PM. Sat 10 AM-7 PM. Buy and sell used gear and have qualified repair facility. ABARIS SYSTEMS, 276 Oriental Pl, Lyndhurst, NJ 07071 (201) 939-0015.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

CODE PROGRAMS. Apple/C-64. 31 modes, graphics, menus, wordprocessor, etc. LARESCO, POB 2018, 1200 Ring Road, Calumet City, IL 60409. (312) 891-3279.

SOLAR ELECTRIC PANELS and System Components. 1st quality for home or repeaters. Lowest prices in country. KA8DSS, RADIANT DISTRIBUTORS, 3900 Dursum, Ada, MI 49301. (616) 874-8899.

HOMEBREW PROJECTS LISTS SASE. WB2EUF, Box 708, East Hampton, NY 11937.

AMPLIFIER BREAKTHROUGH. The current amplifier drives loads push-pull without internal voltage gain. Fastest, quietest circuit in transistor electronics. Plans for quieter audio amplifiers, ideal for home builders, all wattages, $15. Amplifiers Unlimited, Rt. 2, Box 139, Highmore, SD 57345.

NATIONAL HRO-60 parts wanted: coils AA, AB, AC, AD, E, F, G, H, J. Power transformer #SA9209. 4H4 tubes. National Radio logo emblem (front panel mount). K6VRS, 33815 - 133rd Avenue SE, Auburn, Washington 98002 (206) 833-7298.

WA9GFR RF SOFTWARE $15.00 disk contains HF/VHF/UHF/L-BAND propagation and Smith Chart impedance matching programs. Specify Commodore-64 or MS-DOS BASIC. Lynn Gerig, 6417 Morgan RD, Monroeville, IN 46773.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photo-documentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

UHF PARTS. GaAs Fets, MMICs, trimmers, chip caps, teflon pcb, and other builder parts. SASE brings list. MICROWAVE COMPONENTS, 11216 Cape Cod, Taylor, MI 48180.

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, New York 10538.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc, are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.

NEW YORK: June 14. The Hall of Science ARC Hamfest, New York Hall of Science parking lot, Flushing Meadow Park, 47-01-111 Street, Queens. 9 AM to 3 PM. Donations--buyers $4.00; sellers $6.00 per space. Talk in on 144.300 simplex link 223.600 repeat and 445.225 repeat. For information call Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schiffman, WB2YXB (718) 343-0172 evenings.

COLORADO: June 6 and 7. The Northern Colorado ARC is having its 9th annual Superfest, McMillen Building (wheelchair accessible) Larimer County Fairgrounds, Loveland. License exams, technical seminars, CW contest, Army MARS, exhibits, flea market and refreshments. General admission $3.00. Tables $7.50 each advance; $9.00 at the door, includes two chairs and one admission. For reservations contact Duff McRoberts, NF0U, 1308 Ellen Place, Loveland, CO 80537. (303) 669-3708.

MICHIGAN: June 14. The Monroe County Radio Communications Association Swap and Shop, Monroe . 8 Am to 3 PM. Admission $2.50 advance; $3.00 at the gate. Trunk sales $2.00 per space. tables 50 cents/foot. Tickets or reservations contact: Elaine Wessel, KA8RNK, PO Box 237, Monroe, MI 48161 or call (313) 279-1571.

CALIFORNIA: June 21. Father's Day Swapfest sponsored by the Satellite ARC. Union Oil Company Newlove Picnic Grounds south of Santa Maria on US 101. Free general admission 9 AM. Barbeque 1 PM. Price for tickets TBA. Talk in on 145.14 down 600. For tickets and information write Santa Maria Swapfest, PO Box 5117, Vandenberg AFB, CA 93437.

WISCONSIN: July 18. The South Milwaukee ARC will hold its annual Swapfest, American Legion Post 434, 9327 South Shepard Avenue, Oak Creek. 7 AM to 3 PM. Parking, picnicking, food, refreshments and free overnight camping available on grounds. Admission $3.00 includes "happy time" with free beverages. License exams. Packet meeting. For details write South Milwaukee ARC, PO Box 102, South Milwaukee, WI 53172-0102.

MARYLAND: June 21. The Frederick ARC will hold its 10thannual Hamfest, Frederick Fairgrounds. 8 AM to 4 PM. Admission $3.00. Tailgaters $2.00 extra. Non-hams and kids free. For information: Clyde C. Wachter, WB3KQV, 7317 Ridge Road, Frederick, MD 21701.

MINNESOTA: June 6 and 7. The North Area Repeater Association will sponsor the upper Midwest's largest Swapfest and exposition *for Amateur Radio operators at the Minnesota State* Fairgrounds, St. Paul. Admission $4.00 advance; $5.00 at the door. Free overnight parking for self-contained campers June 5 and 6. Giant outdoor flea market. License exams. For information: Amateur Fair, PO Box 857, Hopkins, MN 55343 (612) 566-4000.

INDIANA: June 14. The 41st annual Wabash Valley Amateur Radio Association's Hamfest, Vigo County Fairgrounds, Terre Haute. Saturday night camping $5.00. Sunday 8:00 AM EST. Free outdoor flea market. Covered flea market $3.00. Food and refreshments. Advance tickets $2.00 or 3/$5.00. $3.00 at the gate. FCC exams by pre-registration only. Children under 12 free. Talk in on 147.69/09 and 146.52 simplex. For tickets and information SASE to WVARA Hamfest, PO Box 81, Terre Haute, IN 47808.

PENNSYLVANIA: July 5. 8th annual Wilkes-Barre Hamfest & Computerfest sponsored by Murgas ARC, Ica-A-Rama Coal Street Sports Complex, Coal Street. General admission 8 AM. Donation $3.00. Outdoor tailgating $2.00. Indoor space $8.00. Non-hams and kids under 16 free. FCC exams. Talk in 146.61, 53.61, 146.552. For information K3SAE and KB3GB, Rd 1, Box 214, Pittston, PA 18643. (717) 388-6863.

NEW JERSEY: June 20. The Raritan Valley Radio Club's 16th annual Hamfest, Columbia Park, Dunellen. Gates open 8 AM. Sellers spots $5.00 for one. $10.00 two or more. No tables supplied. Talk in on Club repeater W2QW/R 146.025/.625 and 146.52 simplex. For information call Dave, KA2TSM (201) 763-4849 or Bil, KD2XK (201 467-7342, 8 AM to 5 PM.

PENNSYLVANIA: June 14. Milton AMateur Radio Club's 13th annual Hamfest, Winfield Firemen's grounds, Rt. 15 Lewisburg. Rain or shine. Admission $3.00. Non-hams and kids free. Talk in on 146.97, 146.625 and 146.52. Contact Jerry Williamson, WA3SXQ, 10 Old Farm Lane, Milton, PA 17847.

MICHIGAN: June 6. The Independent Repeater Association is sponsoring its annual Hamfest, National Guard Armory, 44th Street, Grand Rapids. Free tables for dealers and sellers. For table reservations: Independent Repeater Association, 562 - 92nd Street, SE, Byron Center, MI 49315 (616) 455-3915.

NEW JERSEY: GILFER SWL FEST/FLEA MARKET: Saturday, June 13 rain/shine. 9 AM to 3 PM. Shortwave only. Free admission for all visitors. Sellers: $3.00 (tailgate only, bring own table). Reservation deadline: June 1. Location: GILFER SHORTWAVE, 52 Park Avenue, Park Ridge, NJ 07656. For further information please call (201) 391-7887.

MARYLAND: June 10-13. The Antique Radio Club of America will hold its 15th annual National Convention, SHERATON HOTEL AND EXHIBITION CENTER, RT. 450, New Carrollton, 10 miles NE of Washington, DC. The public is cordially invited to attend this 4-day event. Membership information can be obtained from ARCA, 81 Steeplechase Road, Devon, PA 19333.

KENTUCKY: June 7. The Northern Kentucky ARC's "Ham-O-Rama '87", Erlenger, Kentucky, Lions Park. Open to public 8 AM. Admission $5.00. Children under 13 free. Flea market spaces $3.00 each, no tables provided. Contact WA4WNF c/o NKARC, PO Box 281, Florence, KY 41042 (606) 371-2255.

INDIANA: June 21. The Lake County ARC will hold its 15th annual Dad's Day Hamfest, Lake County Fairgrounds, Crown Point. All tickets $3.00. Gates open 8 AM. Talk in on club repeater 147.60/00 and 146/52. Contact: Ken Brown, WD9HYF, 918 Chippewa Drive, Crown Point, IN 46307.

ILLINOIS: June 14. The Six Meter Club of Chicago announces its 30th annual Hamfest, Santa Fe Park, 91st and wolf Road, Willow Springs, SW of downtown Chicago. Advance tickets $3.00. At the gate $4.00. Talk in on K9ONA 146.52 or K9ONA/R 37-97. For advance ticket Mike Corbett, K9ENZ, 606 South Fenton Avenue, Romeoville, IL 60441 or any club member.

CENTRAL ALBERTA RADIO LEAGUE annual Picnic and Hamfest. June 19, 20 and 21.

PENNSYLVANIA: July 4. The annual Firecracker Hamfest sponsored by the Harrisburg RAC, Bressler Fire Company picnic grounds, Harrisburg. Admission $3.00 includes tailgating. Non-ham spouse and kids free. VE exams. For information: Dave, KC3MG, 131 Livingston Street, Swatara, PA 17113 (717) 939-4957.

WASHINGTON: June 6 and 7. Apple City Radio Club's "Come Have a Picnic With Us" Hamfest, Rocky Reach Dam, 7 miles north of Wenatchee, US 97. Free Camping/Trailer space at the Park, Saturday evening banquet, Sunday potluck dinner, Swap Shop, VE exams.

WEST VIRGINIA: July 19. The 9th annual TSRAC Wheeling Hamfest/Computer Fair, Wheeling Park. 9 AM to 4 PM. WV's largest. Dealers welcome 30,000 square feet under roof; 5 acres flea market. Family activities at Park. Admission $3.00 in advance; $4.00 at door. To reserve space contact: Carl Williams, WD8PPS, 9 East High St, Flushing, OH 43977. For tickets: TSRAC, Box 240, RD 1, Adena, OH 43901 (614) 546-3930.

NEW HAMPSHIRE: June 20. Fly-in to New Hampshire's 2nd largest Amateur Radio/electronic flea market, Manchester Municipal Airport. Sponsored by the NH FM Association. Rain date Sunday, June 21. Starts 9 AM. General admission $1.00. Sellers $5.00. Bring table or tailgate. License exams. Talk in on 146.52 FM. For further information on flea market contact Steve Morin, WB1BXB (603) 663-4019 or Dick Desorsiers, W1KGZ, 173 Maplehurst Avenue, Manchester, NH 03103 (603) 668-6868.

PENNSYLVANIA: June 7. The 33rd annual Breeze Shooters Hamfest, White Swan Amusement Park, Rt 60, near Pittsburgh International Airport. Free admission and Flea Market, family amusement park. 9 Am to 4 PM. For information and table reservations Bud Faulhaber, N3DOS, 1059 Balmoral Drive, Pittsburgh, PA 15237 (412) 366-5097.

COLORADO: June 20. The Grand Mesa Repeater Society will hold its 8th annual Western Slope Amateur Radio and Computer Swapfest, 9 AM to 4 PM, National Guard Armory, 482-28 Road, Grand Junction. Free admission. Swap tables $5.00 each. Indoor swapfest, Amateur Radio exams, auction and refreshments. Talk in on 146.22/.82 and 449.20. For tables or information SASE to Les Scott, NV0F, 2105 Yellowstone Rd, Grand Junction, CO 81503 or call (303) 242-5296.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.

VIRGINIA: June 7. The Ole Virginia Hams present the Annual Manassas Hamfest, Prince William County Fairgrounds. 8 AM to 4 PM. General admission $4.00. Children under 12 free. Tailgating $5.00/space. Dealers, ARRL booth, CW proficiency award. Talk in on 146.37/97, 146.52. For information write: Ole Virginia Hams ARC, POB 1255, Manassa, VA 22110. John Gunsett, KI4VP (703) 361-5255 or Gene Roberts, N4HFW (703) 361-3983.

MICHIGAN: June 7. The Chelsea Swap and Shop, Chelsea Fairgrounds, Chelsea. Sellers 5 AM. Buyers 8 AM to 1 PM. Donation $2.50 advance and $3.00 at the gate. Children under 12 and non-ham spouses free. Talk in on Chelsea Repeater 146.980. For information: Robert Schantz, 416 Wilkinson St, Chelsea, MI 48118. (313) 475-1795.

OPERATING EVENTS

"Things to do . . ."

June 19 to 21: The Six Meter International Radio Klub, Inc. announces their 12th annual SMIRK PARTY Contest. SASE for log requests to Lisa Lowell, KA0NNO, PO Box 547, Hugo, CO 80821.

June 6 and 7: The Wireless Institute of Northern Ohio (W.I.N.O.) will have a special events station to commemorate Ohio Wine Month. The station will be operating from a winery in Madison, Ohio and will use callsign K080. For a special certificate send legal SASE to KC80 WINO Weekend, 7126 Andover Drive, Mentor, Ohio 44060.

June 26—28: The Ottawa ARC will operate W8MCB from 1700Z to 2300Z to celebrate the 175th anniversary of establishment of the Fort during the War of 1812. For a commemorative certificate send QSL and SASE to WD8RJR, Paul Baumgarte, RR #3, Box 341, Delphos, Ohio 45833.

July 11 and 12: Oklahoma Amateur Radio Operators will conduct their 4th annual "Field Day" exercises at Lake Canton, OK. Activites begin 2 PM Saturday through noon Sunday. For additional information contact Tim Mauldin, WA5LTM, Lake Canton Field Day, PO Box 19097, Oklahoma City, OK 73144 (405) 521-5048.

ELMER'S NOTEBOOK

Tom McMullen, W1SL

elmer's notebook

Welcome to *ham radio*'s new feature: Elmer's Notebook. You're going to find it informative, interesting, and — we hope — useful in many ways.

who's Elmer?

Elmer is the person who helped us at one time or another, either in our efforts to get started or in trying something new in Amateur Radio. Although he wasn't necessarily an old-timer, he had considerably more experience than we did. Who was he?

Maybe *you*! Many of you have been Elmers without realizing it. Some would have been mildly embarrassed if caught in the act. But Elmers you have been, nevertheless.

For some, being an Elmer is actually a hobby within the hobby. Dedicated Elmers spend large amounts of time helping newcomers bone up for exams and acquire their first rigs. They're always available to critique the new fist or help calm the first-contact jitters.

That's what this new column is all about — to provide guidance, encouragement, and useful material for the Elmers among *ham radio*'s readers. Of course, if Novice or other licensees find Elmer's Notebook helpful or thought-provoking, that's great too!

novice enhancement

Novice Enhancement has been in the works since April, 1986, when the FCC adopted a Notice of Proposed Rule Making (NPRM) in response to several petitions. After several hearings and response periods, it finally became official on March 21, 1987: Novices now have expanded privileges that provide immense possibilities for communication and enjoyment on the 10-meter band, and new privileges in the 220- and 1270-MHz bands. **Figure 1** shows the relationship of these segments to other parts of the Amateur Radio spectrum. The shaded areas indicate the modes Novices are permitted to use on those band segments. Power levels are 200 watts PEP on 28.1 to 28.5 MHz (this same power restriction applies to Technician class licensees on this band), 25 watts PEP on 222.1 to 223.91, and 5 watts PEP on 1270 to 1295 MHz.

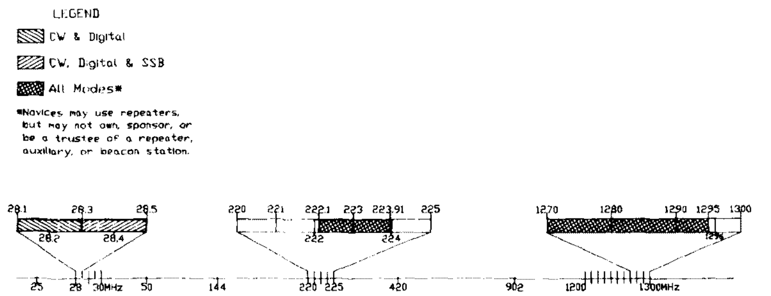


fig. 1. New Novice band privileges.

These power levels are reasonable. They're adequate for plenty of exciting communications, either direct or through repeaters, yet still offer incentive to upgrade to a higher license in order to expand capabilities. Though the 5-watt limit at 1270 MHz may seem low at first glance, it's ample for use through repeaters and for direct communication via hand-held equipment or mobile and fixed stations. There is a concern for safety at these higher frequencies; until the operator has learned enough to understand why caution is essential, low power levels are prudent indeed. We'll talk more about this aspect of operation in future columns.

the challenge

These new privileges and frequencies not only give Novices room for growth, but also generate a challenge for us Elmers: to help Novices respond to the FCC's strong recommendation, voiced in its Report and Order, that current licensees "become knowledgeable in the new requirements before using the new privileges." It's up to us to, advise them about techniques, equipment, and procedures required for the new modes of communication and on the new bands so they'll be comfortable when they try them — and so they can enjoy these privileges without creating problems simply because they haven't been there before.

Along with this primary challenge

comes a second one — to prepare prospective Amateurs for the ten new questions to be incorporated into the revised Element 2 exam. (All Novices licensed before March 21 will be "grandfathered" into the new privileges.) If we do our homework and work toward meeting the primary goal, we'll be better prepared for meeting the second.

There shouldn't be much trouble in explaining voice modes (with the possible exception of answering the questions about PEP). Novices have been waiting to try voice for a long time, and have had plenty of time to listen to voices on the high-frequency bands, just a twist of the dial away from their own CW segments.

Digital modes? Now it gets interesting. Digital communications is a relative newcomer to the Amateur Radio bands. The newest facet of that mode is packet radio, with AMTOR a close second. RTTY has been with us for quite a while, but its image has changed dramatically over the years. I can still recall the heavy, noisy, cranky monster that I assembled back in the late 1940s — but that's another story.

As I peruse the exhibitor's booths and the flea markets at hamfests, I note many small, neat, RTTY demodulators that fit handsomely on the operating desk, work with almost any common computer setup, and make very little noise. They use less power than it took to just light the filaments in the tubes in my early rig. (Filaments? Oh, they were like heating elements down inside the tube, and their function was to get the adjacent metal hot enough to excite the electrons so they'd be easier to manipulate. Filaments also made a nice cozy glow in a darkened room, made the watt-hour meter spin merrily, and told you immediately that the tube was on.) Although today's digital equipment is as far ahead of RTTY as the new RTTY demodulators are ahead of the military surplus that clanked out endless RYRYRY messages in the 1950s, RTTY is still an attractive means of communication.

Obviously, the Novice license is taking beginners into much more interesting and complex technology, and we should be prepared to provide answers and guidance. The new segments on 220 and 1270 MHz offer many exciting possibilities. Just a few of the inevitable questions include "What can be done at these frequencies?" "What's their communication range?" "Where do I get equipment?" "What about antennas?" And — here's a good one — "Can I send television on 1200 megs?" There are many answers to search for and lots of exciting territory to explore. We're here to help.

Next month, we'll take a closer look at the specific privileges indicated in **fig. 1**. In future issues, we'll discuss equipment and operating procedures, and provide information to help you prepare would-be Amateurs for the new Element 2 exam questions.

ham radio

Welcome Back, Tom

With this first installment of "Elmer's Notebook," we welcome Tom McMullen, W1SL, former managing editor of *Ham Radio Horizons*, back to *ham radio*.

Tom's involvement in radio began during his days as a Navy radio operator on a cruiser in the Pacific during World War II. First licensed in 1947, Tom credits much of his early growth in Amateur Radio to *his* Elmer, the late W8GBF.

Although his initial interest was in handling traffic on 80 meters, Tom moved on to VHF and microwave communications in the early 1970s and remains active in those areas today. He and his wife Eleanor, W1RNT, live in Florida, where Tom is employed as publications manager for a major electronics firm. — Ed.

JULY 1987 / $2.50

annual VHF/UHF issue

ham radio magazine

focus on communications technology

ham radio magazine

JULY 1987

volume 20, number 7

T. H. Tenney, Jr., W1NLB
publisher

Rich Rosen, K2RR
editor-in-chief
and associate publisher

Dorothy Rosa, KA1LBO
managing editor

Tom McMullen, W1SL
Joseph J. Schroeder, W9JUV
Alfred Wilson, W6NIF
associate editors

Susan Shorrock
editorial production

editorial review board

Peter Bertini, K1ZJH
Forrest Gehrke, K2BT
Michael Gruchalla, P.E.
Bob Lewis, W2EBS
Mason Logan, K4MT
Vern Riportella, WA2LQQ
Ed Wetherhold, W3NQN

publishing staff

J. Craig Clark, Jr., N1ACH
assistant publisher

Rally Dennis, KA1JWF
director of advertising sales

Dorothy Sargent, KA1ZK
advertising production manager

Susan Shorrock
circulation manager

Therese Bourgault
circulation

Hans Evers, PA0CX
cover

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00; three years, $74.00
Europe, Japan, Africa (via Air Forwarding Service): one year, $37.00
All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 89

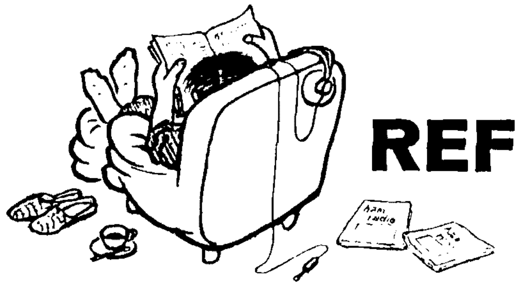
Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents



REFLECTIONS

13 cm: onwards and upwards

Some view the spectrum above 1 GHz as a vast, sterile desert devoid of life, difficult to get to, and of questionable worth once attained. But, just as in the desert (which, of course, teems with life), what you see isn't necessarily what you get.

To the uninitiated, fear of the unexplored prompts questions such as "What the heck's it good for?, "Who can I talk to?", and "How do I get there in the first place?" These aren't bad questions, but they've all been asked before — about 5 meters, 2 meters, 70 cm, and most recently, 23 cm. Yet saturation of 2 meters is a fait accompli in many areas; 70 cm isn't far behind, and 23 cm is being staked out by many repeater operators looking for turf.

One senses repetition of a familiar pattern. Any "new" band is first occupied by the desert rats who build their own transmit and receive converters, antennas, and preamps. A few of them begin selling their special boxes to friends; soon, the more entrepreneural types among them begin marketing the product on a limited scale. Later, when the commercial possibilities are obvious, the large, established manufacturers jump in. With their sizeable R&D and engineering resources, they quickly develop commercially attractive boxes, with legible control labels replacing the chicken scratches on bare aluminum typical of the earlier models.

To potential users of the new band, operation now becomes much more feasible. No new skills need be acquired. Often, simply knowing how to use a credit card is sufficient: just unpack the box, hook up the unit, and you're *there*.

By my reckoning, critical momentum for 2 meters was achieved in 1971 or 1972; for 70 cm, in 1978 or 1979; and for 23 cm, in 1984 or 1985. By the same measure, I figure "critical mass" for 13 cm (2.4 GHz) will occur sometime about 1989 or 1990. All indicators suggest that a big push into this band is imminent. Entrepreneurs now offer 13-cm transverters, loop yagis, and preamps. Moreover, military and commercial applications of S-band systems, equipment, modules, and components have fueled development of low-cost microwave devices (including integrated circuits) to the point where getting on 13 cm is much less expensive than it was just a few years ago. Obviously, since cost is a predominant design driver in the Amateur market, this development is of paramount interest to would-be manufacturers of 13-cm Amateur equipment.

The demands for spectrum and services in the lower Amateur bands (70 cm and below) exert continuous pressure to move to less congested territory. Digital communications, particularly packet radio networking and digitized voice and video, are notable forces propelling users up to 23 cm and soon, on to 13 cm.

In the context of 13 cm, the answer to the familiar question, "Who can I talk to up there?", may differ from the answers that were appropriate when the question was raised in regard to 70 cm and 2 meters. This is because important breakthroughs are now occurring in the development of Amateur satellites (OSCARs) — in the frequencies to be used, the modes to be employed, and the platforms (i.e., satellites) used to carry equipment into space. More significantly, however, these breakthroughs may finally allow more Amateurs than ever before to participate in satellite communications.

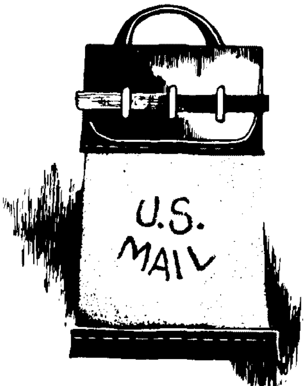
The first steps will be modest. In 1988, AMSAT will launch Phase 3C, with four transponders aboard; one of these will be a small 70-cm uplink, 13-cm downlink fm repeater. This easily acquired downlink may carry fm voice bulletins suitable for linking through gateway repeaters.

Just a few years from now, in 1991, AMSAT's Phase 4 geosynchronous satellite will provide several classes of service at 13 cm, including voice and data as well as gateway linking, so that hams using HTs in one city will be able to interconnect through a local gateway with gateways and HTs in another. So the question, "Who can I talk to on 13 cm?" will soon be answered by "Who would you like to talk to?"

Progress in these areas will bring new problems, however. As advances in technology drive down the cost of Amateur UHF and SHF equipment, commercial interests will find those portions of the spectrum increasingly appealing. Even now, they're eyeing the seemingly infertile UHF territory for suitable enclaves. The Amateur allocation at 13 cm is looking more attractive than ever, and has quickly become interesting real estate to those who would sell services based on occupancy of S-band spectrum.

This means that Amateurs can't afford to delay making productive use of the 13-cm band. In short, we need to get busy and make that 13-cm desert bloom — with useful public service and emergency communications services, packet radio networks, and educationally significant communications as well as our traditional goodwill-building communications. Let's keep our hold on that band by planning for meaningful occupancy and by supporting those concrete efforts towards widespread utilization of 13 cm — such as Phase 3C and Phase 4 — already underway.

Vern "Rip" Riportella, WA2LQQ
President, AMSAT



comments

DARC awards

Dear HR:

Many DXers in the United States and Canada either do not know that there is such a thing as a "Worked All Europe" (WAE) or other DARC awards, or are afraid to send their cards to Europe because of the cost and the possibility of loss.

I am now the United States/Canadian checkpoint for all DARC awards. All information, including a list of countries, plus record sheets and application forms, can be obtained from me for a No. 10 SASE plus $1.00.

Ralph M. Hirsch, K1RH,
Woodbridge, Connecticut 06525

for the birds

Dear HR:

I was intrigued with Bernard Kirschner's request for ideas on how to discourage live owls from attacking a plastic owl installed as a bird-deterring antenna ornament (Comments, May, 1987, page 6).

As a salesman, I call regularly on a company that had a similar problem. A small park in the company's front yard was beautiful until the birds came, complete with droppings. Walking through the park turned into an inspiration to take up jogging — make that *sprinting*.

Fortunately, this is a high technology company full of bright scientists and engineers ready to tackle any problem. First they tried a plastic owl, deployed in a variety of locations in the park with little noticeable effect. Then they tried directing ultrasonic pulses at the park — no effect. Finally, they hung a life-sized plastic eagle from the middle of a drooping wire (you might try nylon rope in order to avoid interfering with antenna patterns) suspended about 20 feet above the park. As the eagle moves up and down in the wind, it spreads its wings, discouraging smaller birds.

Nature's pecking order puts the eagle at the top of the birds' list of daytime predators. Being nocturnal, owls prey mostly on rodents; perhaps that's why few smaller birds have learned to fear them?

I hope this idea helps.

John D. Seney, KB1HE,
Manchester, New Hampshire
03013

hams of the future

Dear HR:

I want to thank everyone who contributed to my receiving AEA's 1986 Ambassador award, which I accept on behalf of all of us who have been sharing our hobby with "outsiders" for years. AEA's award thrusts the Redwood Youth Foundation's program into high visibility.

We now have academically accredited ham radio classes in three secondary schools in Santa Cruz, with several more planned, and many other schools pleading for us to initiate the program for them. All this has been made possible by Ben Deovlet, WB6FDU — our chief donor, tech advisor, and cheerleader for the past five years — as well as many other generous hams who contributed gifts of time, effort, and equipment.

Thanks to these many donors and volunteers, the Redwood Youth Foundation has sponsored several International Youth TeleCongresses and conducted multinational Teleconferences via computer. . . all for less than the cost of one field trip to the zoo per school!

All this attracts young people of all colors, creeds, and ideologies. We've never seen so many young people so totally electrified, as they network with peers everywhere, learning how to communicate and cooperate.

Young networkers need *your* expertise! How about volunteering to be the school program facilitator in *your* town?

Jack Anderson said, "Every generation, if it is to fulfill itself, must have a dream to inspire it and an adventure to ennoble it." I invite all of us to help inspire and ennoble this generation of teens. History is waiting for us to take our kids with us as we explore our new, almost infinitely expandable electronic "space."

Mary Duffield, WA6KFA
Santa Cruz, California 95062

short circuit

compact 20-meter travelradio

In K1BQT's article, "Compact 20-meter CW Travelradio" (June, 1987, page 8), part numbers were omitted for the following:

CW filter IC	1458 dual op amp
Q8	2N3906
Q9	MPS2222
Q10	BS-170
Q11	MRF479

With the exception of MRF479, all of the above parts are available from Radio Shack; the MRF479 is available from RF Parts, 1320 Grand Avenue, San Marcos, California 92069.

Figure 7B (main board layout, page 19) should have indicated the positioning of the ICs; the key on U4 goes toward the 10 μF electrolytic, and the key on U2 goes toward T2 (IF can). In **fig. 10B** (CW audio filter), the key on the 1458 op amp goes away from the 10 μF electrolytic.

The 914 diode shown located next to the 20-k trim pot (S-meter zero control) in **fig. 7B** should be designated as a 9.0-volt, 400-milliwatt zener diode (Z1 in parts list).

SHORT CIRCUIT HOTLINE

Building a current *ham radio* project? Call the Short Circuit Hotline any time between 9 AM and Noon, or 1 to 3 PM — Eastern time — *before* you begin construction. We'll let you know of any changes or corrections that should be made to the article describing your project.

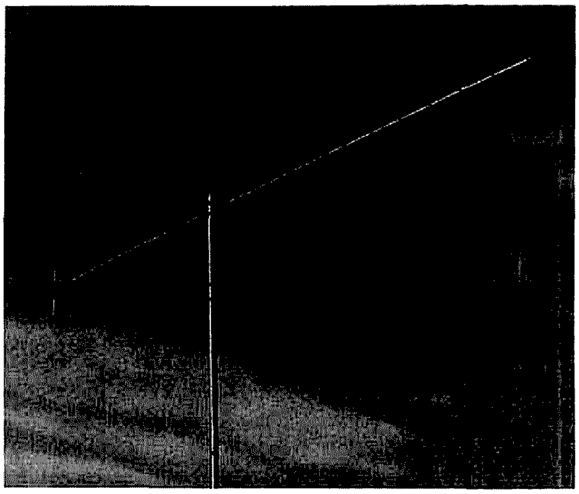
(See "Publisher's Log," April, 1984, page 6, for details.)

603-878-1441

high-performance Yagis for 432 MHz

Practical application of computer analysis

This article describes two long Yagis for 432 MHz. Both offer excellent gain, given their boomlengths, and exceptionally clean pattern. Details of the development and construction of these Yagis, which were designed to be easily built from a commercial antenna, are given. In addition, dimensions are presented for two higher gain Yagis which offer even better theoretical performance, but have not yet been checked by the construction of test antennas.



The Cushcraft 424B offers sound mechanical construction at a reasonable price.

few 432 MHz designs

Three years ago I was searching for a good Yagi design to use in a new 432-MHz array. The selection of commercially available antennas for 432 MHz has always been very limited because the number of stations active on 432 MHz is small enough to make the design and production of commercial antennas for this frequency a proposition of limited, if any, profitability. Consequently, manufacturers have been slow to incorporate the latest developments in Yagi design.

Fortunately, Günter Hoch, DL6WU, had developed a director spacing and length combination which offered very good gain, a relatively clean pattern, and the ability to easily lengthen or shorten the Yagi without causing the gain peak to shift appreciably.[1] In all, the DL6WU design was a significant improvement over most previous Amateur designs. Several United States Amateurs had discovered this information and successfully built 432-MHz Yagis from it.

The use of Günter's design data required a start-from-scratch approach. However, most Amateurs find building antennas from scratch is unacceptable because of the lack of convenient sources of materials and the necessity of construction equipment and machining skills. Modifying a commercial Yagi to perform as well or better than the DL6WU design allows more Amateurs to experience the benefits of a high performance 432-MHz antenna system.

improving a good design

The starting point for the development of these Yagis was the Cushcraft 424B, which offered sound mechanical construction at a reasonable price. By

By **Steve Powlishen, K1FO**, 816 Summer Hill Road, Madison, Connecticut 06443

working from a proven design, it was possible to reuse most of the components and hardware to make a good product even better.

better pattern, higher gain

My goal was to increase the gain, clean up the radiation pattern of the antenna, and get an acceptable wet-weather VSWR, while widening the gain bandwidth. The initial project was so successful that an extended boomlength version was also perfected.

An initial look at the 424B shows that it uses one close-spaced director of 0.135 wavelength spacing, a second director spaced at 0.368 wavelength, and the rest of the directors spaced at 0.375 wavelength. The first ten directors have a length taper. The final ten are all the same length. Long Yagis (over 5 wavelengths), which use constant director spacings, generally have radiation patterns with very high sidelobe levels and overly narrow main lobes. In addition, such director arrangements create Yagis with narrow gain bandwidths and a very sharp gain dropoff on the high frequency side of the gain peak. Design improvements are even more beneficial when the Yagi is used in an array. Reference 2 illustrates this relationship. Mutual impedance effects, which tend to lower the gain peak frequency of an array versus the individual Yagis, also magnify these shortcomings in an array.

One little-known aspect of the NBS study was that the researchers tried designs up to 7 wavelengths long. These longer Yagis were not included in the formal NBS report (*NBS Technical Note No. 488*), however — probably because of their poor performance. NBS researchers faced the limitations of constant spacing Yagis over 30 years ago; unfortunately, the NBS study wasn't extended to include variable spacing Yagis.

The development of these new Yagis began on a backyard antenna range. The first step was the addition of another close-spaced director, which improved the pattern but gave no significant gain increase. Application of directors with a constant taper gave further pattern improvements but still no meaningful gain increase. The time and effort required to build and measure the different antenna designs gave me some insight as to why Cushcraft ended their development of the 424B at the point they did: the task of optimizing the directors' lengths while simultaneously keeping the Yagi's gain peak near 432 MHz and maintaining a reasonable driven element match appeared to be overwhelming.

computer analysis helped

The WB3BGU series of articles on the computer analysis of Yagis[3] ended with a description of the computer program, which *ham radio* made available to readers for an SASE. Initially, I set up the program in FORTRAN (in which the original was written) on a computer at work; I then translated it to BASIC, which could be run on a home computer. The translation to BASIC gave me the opportunity to correct some bugs in the program and add graphics routines.

I spent the next three months analyzing every Yagi design for which I could get dimensions, paying special attention to designs with reliable pattern and gain data. Such an examination of the program was deemed necessary in order to ensure that any design created with the program would offer realistic results.

Computer analysis of various designs confirmed the desirability of both additional close-spaced directors and an element taper to improve the pattern of the Yagi. Antenna modeling indicated that continuously increasing spacing, as used by DL6WU, was *not* necessary to create a high performance Yagi. In fact, it appeared that several less complicated spacing patterns could be used as long as all element lengths were optimized for that chosen spacing. An important step in the design of the improved Yagi, it was intended to retain as many of the original 424B element spacings as possible in order to simplify construction.

There are distinct advantages of the DL6WU design approach. The foremost is the ability to add or subtract directors without having the gain peak frequency shift appreciably. A number of designs were examined for frequency shift as elements were added. It was found that the center frequency of all Yagi designs oscillates up and down as elements are added. Even the DL6WU design shows this tendency, though the effect was the least of all designs examined. The wide gain bandwidth of the DL6WU design also minimized any frequency shift effects.

The 24- and 32-element designs presented here all have similar dimensions. Note that the directors of the 24-element Yagi are shorter than the 32-element version. Both Yagis have been adjusted to have a gain peak that's very close to the same frequency (436 MHz), even though the elements lengths are different for the two Yagis. One should be forewarned that if construction of a Yagi from this design with a different number of elements is attempted, its gain peak may be several MHz away from that of the 24- or 32-element antennas.

variable element lengths and spacings

The Yagi designs presented in this article use both varying element spacings and lengths. This was consistently found to give not only the highest gain, but the cleanest patterns and widest gain bandwidths. DL6WU pointed out the theoretical reasons for this condition.[4] Long Yagi designs which use either con-

stant element spacings or element lengths give poorer performance and should no longer be worthy of consideration for use by VHF/UHF weak signal operators.

The formal design of the 432-MHz super Yagis started with a selection of varying director spacings. These were chosen to fit best within the existing element holes to minimize the necessity of drilling new holes in the boom. I tried adapting the DL6WU spacing pattern to the 424B; except for the final director, spacing became 10.25 inches (260 mm) or 0.375 wavelengths, since that was the ultimate spacing of the 424B. The DL6WU design used a final spacing of 11 inches (280 mm) or 0.400 wavelengths. Electrically, this approach appeared to work very well. Mechanically, however, this was not an acceptable solution because eight or nine new holes would have to be drilled into the boom — not in keeping with the relatively simple modification I was hoping to develop.

Next, five different new spacing patterns were examined on the computer. It was apparent that a good progressive spacing pattern didn't fit easily within the existing holes. The solution was to move the position of the driven element. Once this was done, an acceptable spacing arrangement was adapted to the 424B. The extra effort in devising this new director arrangement paid off by making a new design that requires only three new element holes to be drilled in the boom.

Though not yet the ultimate answer, this extensive computer analysis (and in general, use of the computer in antenna design) helps to dispel several long-standing myths Amateurs have maintained about Yagi design. The first myth is the notion that a design has to be optimized for either highest gain or best radiation pattern. It was found that for designs with proper variable spacing arrangements, the best gain and best pattern solutions were convergent. While a design could be adjusted to maximize any particular aspect of the radiation pattern (lowest first sidelobes, highest f/b), the best overall pattern quality occurred concurrently with the highest forward gain *solution*. The only way to further improve the pattern was to move the operation point of the Yagi lower on its frequency response curve — i.e., slightly shorten all of the directors. I found that first sidelobe strengths were usually close to −18 dB in the E plane and −16 dB in the H plane when a Yagi with a good spacing pattern was optimized. Students of physics will recognize the significance of −18 dB because it's the expected strength of the first sidelobes from a fully illuminated circular aperture.

Another common myth holds that when a Yagi is tuned for maximum gain, its bandwidth will be very narrow. This condition was found to be true for constant spacing and constant length designs, but it was also true for those constant designs *even when they were not gain optimized.* For designs with variable spacings and lengths, the gain bandwidth of such designs was remarkably wide. Even more significant was the fact that the gain bandwidth was best when the elements were optimized for maximum forward gain. As an indication of this wide gain bandwidth the 24-element modified Yagi has a −1.0 dB gain bandwidth of 25 MHz! (Gain bandwidth should not be confused with VSWR-bandwidth. VSWR bandwidth is merely an indication of feed impedance versus frequency and is not normally an indication of forward gain.)

single reflector used over trigon

At this point I decided to drop the tri-reflector arrangement in favor of a single reflector. There have been some exaggerated claims made for various multiple reflector arrangements. Previous experimental work indicated that any of the various multiple reflector arrangements gave about 0.2 dB additional gain over a single reflector, once they were optimized for the individual Yagi design to which they were added. Subsequent computer analysis has indicated that the amount of additional gain obtainable in these multiple reflector arrangements decreases in direct proportion to how well the directors are optimized. That is to say, an antenna that doesn't have its directors fully optimized for maximum forward gain could very well see 0.5 dB additional gain with the addition of a tri-reflector or screen reflector. Conversely, a Yagi with its directors optimized for maximum gain may be fortunate to see a 0.1-dB gain improvement from such a multiple reflector arrangement.

There also seems to be a common misconception that multiple reflector arrangements improve the f/b ratio. Except for screen or grid reflectors such as those used by DL9KR, this has not been observed to be the case.[5] Dual or tri-reflectors show some tendency to increase the bandwidth over which a particular f/b will be maintained, but don't show any consistent tendency to always increase the f/b. Many of these multiple reflector arrangements can be tuned to decrease the strength of the rear lobe right at 180 degrees. Since the overall gain of the Yagi doesn't significantly increase with these multiple reflector arrangements, the strength of other minor lobes increases. It should also be noted that the actual f/b at the 180-degree point of the pattern is not a good indicator of the performance of a Yagi. Many Yagis, including the stock 424B and F9FT-21 element Yagi have nulls at the 180-degree point which give an artificial sense of a high f/b. In order for a Yagi to have an excellent G/T (Gain-to-Noise Temperature ratio), it must have all lobes in the rear hemisphere of the Yagi, *in all planes*, down a significant amount (over 25 dB). Lobes on either side of 180 degrees are actually conical in shape when the antenna pattern is viewed in three dimensions. There-

fore, they intercept a large amount of radiated energy and can be a troublesome source of noise reception. The modified Yagis have measured f/b ratios of close to 25 dB. In addition, the lobe at 180 degrees is strongest in the rear hemisphere of the pattern and almost all other rear lobes are down 30 dB or more.

If a high or broadband f/b ratio is desired, a non-tuned grid or screen reflector arrangement will be most effective. If one is concerned mainly with forward gain and pattern at a particular frequency, none of the multiple reflector arrangements is as effective in terms of windload versus additional gain when compared to simply lengthening the boom and adding more directors.

The quad-type feed and reflector were also examined. Many of the performance claims for the quad feed were not substantiated by computer analysis. It was found that on short Yagis (under 1.5 wavelengths) the quad feed added a couple of tenths of a dB in additional gain versus a dipole feed. However, in considering the quad feed and reflector, one must also account for the additional windload and weight that it adds. As in the tri-reflector, the gain-versus-windload war would be won by adding directors to a dipole-fed Yagi. The longer the Yagi was, the less effect the quad feed had. In fact, at 5 wavelengths (boom), no measurable gain advantage was noticed by using a quad feed and reflector.

One area in which a quad feed can offer an advantage is in VSWR bandwidth — i.e., the VSWR could be held under a certain value over a wider frequency range. If a quad feed is used on a long Yagi, I highly recommend using a balun. Pattern measurements on quagi-type antennas have usually shown significant pattern imbalances. Another myth about quagis has been that they have better patterns; yet an examination of existing quagi designs, both on the computer and on my antenna range, indicated that their patterns are substantially poorer than any modern Yagi such as the DL6WU design or the designs presented here. Attempts were made on the computer to adapt the quad feed to more modern director strings. The results were not very successful. The quad feed seemed to require a very wide first director spacing in order to get acceptable forward gain. This wide first director spacing then caused pattern deterioration. The net result was to drop further efforts on quagi-type antennas.

design knowledge reduces computer time

The computer hardware available to me over a year ago required about 2-1/2 minutes to calculate the gain and pattern of the 24-element Yagi and close to 4 minutes to calculate the 32-element version. Considering that every time an element length was changed, every other element had to be checked to see if its length should also be changed, the number of calculations required to optimize each of the elements might require sitting at the computer for half a year. To free me from that chore, I designed an algorithm to optimize the element lengths automatically. This algorithm could also be utilized to optimize element spacings. It could be extended to optimize both spacings and lengths as well; however, with the level of computer power available to most Amateurs, such an optimization of a 32-element Yagi might take considerably longer than we're willing to wait. Therefore, the design must start with some geometry constants determined by the designer's knowledge of antenna designs.

It was found that the Yagi analysis program lacked sufficient accuracy to completely self-optimize a long Yagi. Specifically, the program showed a tendency to make the elements at either end of the antenna longer than desired. In addition, the program would make the elements in the center of the Yagi considerably shorter than would be believable. At the same time, gain figures would become higher than expected. Moreover, the free-running gain optimization would result in an antenna with a low f/b ratio (less than 15 dB). Therefore, it was necessary to go into the design process manually from time to time and correct element lengths that appeared to be out of line. These adjustments were based on real-world experience with designs which were known to work. Final manual element adjustments were made to perform pattern cleanup on the Yagi.

With a good mathematical model in place, the next step was to build and test a real antenna. This is the point where theory meets reality; if an antenna is optimized with even a slightly erroneous model, those errors will surely be designed into the resultant Yagi. A further complication was the use of elements mounted through the boom but insulated. At that time, no reliable element length correction information existed for that method of mounting elements. An additional uncertainty was the fact that very few existing 432-MHz Yagis peaked very close to 432 MHz on the computer. First attempts to build real 24- and 32-element Yagis resulted in antennas which peaked in gain around 444 MHz.

This occurred for several reasons. First, the design was intentionally peaked high in frequency because the Yagis were designed to be used in arrays of up to 16 elements. In addition, at the onset of antenna construction, I expected a much smaller boom correction for insulated through-the-boom elements than the actual correction factor turned out to be. Another set of elements were made 1/16-inch (1.6 mm) longer. This lowered the gain peak to 442 MHz. An additional set of elements were made for the 32-element Yagi again 1/16-inch (1.6 mm) longer. The gain peak moved

another 2 MHz lower to 440 MHz. Both the real antenna and additional computer modeling showed that a 432-MHz Yagi with 3/16-inch (4.8 mm) diameter elements shifted in frequency approximately 1 MHz for each 1/32 inch (0.8 mm) added or subtracted from the elements. Since 1/32 inch is also very close to 1 mm, this becomes a handy rule of thumb for shifting the center frequency of a 432-MHz Yagi for those working in either English or metric units.

boom correction

During this phase of antenna development I examined the boom correction. Three different insulators — the original 424B type (Heyco nylon inserts), the Delrin™ RIW Products type, and the KLM polyethylene type — were tried; all three gave similar, but not identical, results. The amount of capacitance between the element and boom appeared to be the major variable in boom correction. In modeling the effect of the insulated elements mounted through the boom, one can think of the element as an inductor. The boom is looked at as additional inductors in parallel with the center portion of the element. For insulated elements these inductances are capacitively coupled, reducing the amount of parallel inductance. This lowers the amount of boom effect over elements mounted through the boom and not insulated.

Figure 1 describes the boom correction model. An additional complication in the model is an apparent shielding effect that the boom has on the portion of the element which is inside the boom. This increases the boom correction over the amount implied by the simple capacitive/inductive reactance model. The correction I normally use for this type of element mounting is 25 percent of the boom diameter. The effect appears to change slightly with boom diameter. For example, a 0.75-inch (19 mm) boom shows closer to 20 percent correction, while a 1-1/2 inch (38 mm) boom requires nearly 30 percent correction. This nonconstant effect was also charted by DL6WU for uninsulated elements mounted through the boom.[6] The −0.5 dB gain bandwidth of a well-designed Yagi is close to 3 percent, or nearly 14 MHz at 432 MHz. Because of this, one doesn't have to be all that fussy in the exact determination of the boom correction.

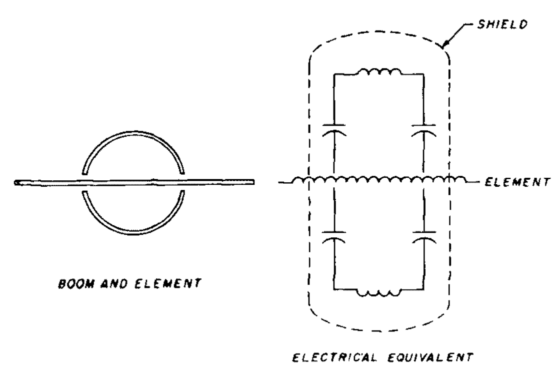


fig. 1. Insulated through-the-boom element modeling.

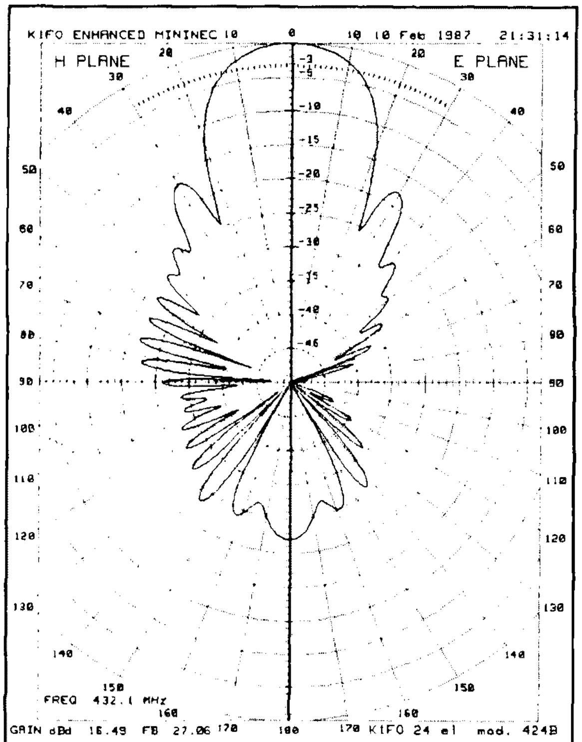


fig. 2. Calculated E and H plane pattern for 24-element Yagi, version 3.

square cut end lengthens element

Another impediment to having the computer model come out right the first time is what I call the *element end effect*. This is an apparent effect where a rod element with square cut ends will appear electrically longer than its physical length. I believe the sharp corners at the end of the element cause a field strength concentration; a more even current and field distribution would be obtained by using elements with spherical ends.

This effect is probably negligible below 50 MHz. At 432 MHz, where a 3/16-inch (5 mm) diameter is a measurable portion of a wavelength, the effect can no longer be ignored. I believe this element end effect is the main reason Amateurs had so much trouble scaling Yagis to 432 and 1296 MHz for many years; it's also further substantiated by persistent stories that the NBS Yagis wouldn't work above 1000 MHz. Most likely the element length graphs provided by NBS did not have this factor taken into account for frequencies significantly different than the 400-MHz test frequency used by the NBS.

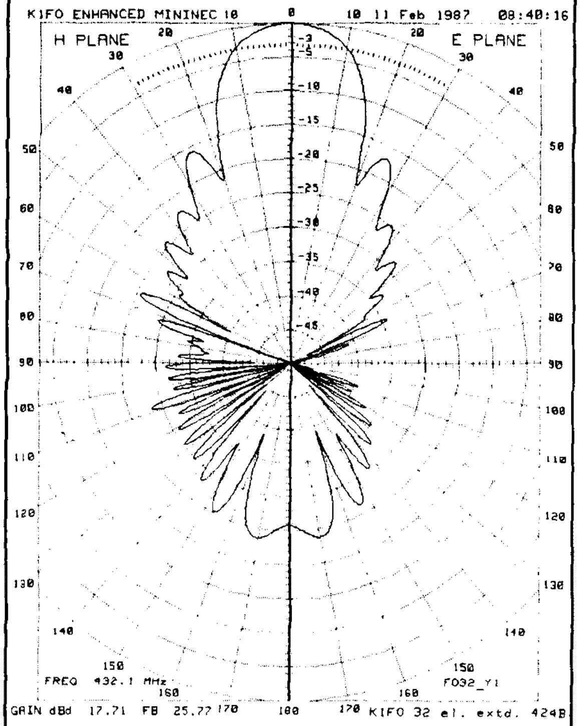


fig. 3. Calculated E and H plane pattern for 32-element Yagi, version 2.

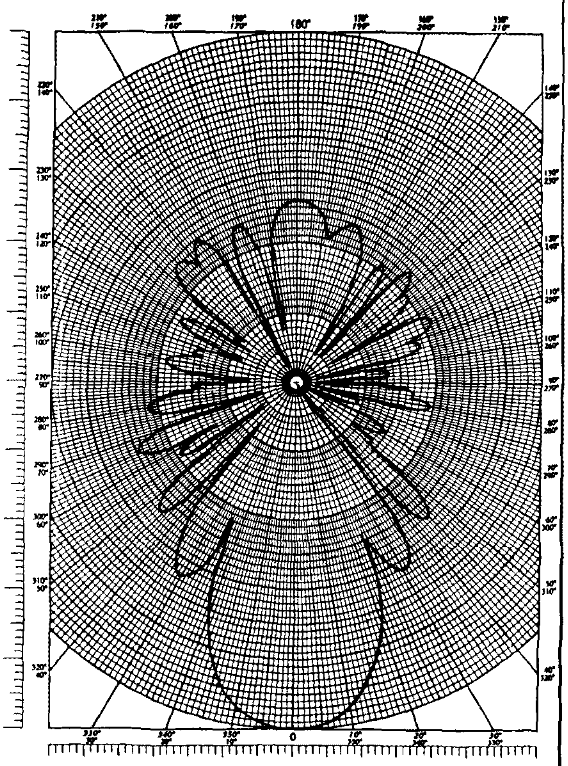


fig. 4. Measured E plane pattern of modified 24-element Yagi, version 3.

My work leads me to believe that at 432 MHz, a 3/16-inch (4.8 mm) diameter element with square cut ends acts as if it were close to 0.15 inch (3.8 mm) — electrically longer that its physical length. Using the previously outlined nominal 1-MHz frequency shift per 1/32 inch (0.8 mm) of element length change rule of thumb, this element end effect accounts for close to a 5-MHz lowering in center frequency at 432 MHz. To minimize this effect and to help lower the field concentration at the element ends, I use about a 1/32-inch (0.8 mm) chamfer on the element ends. This appears to reduce the frequency shift to less than 2 MHz. *This rounding of the element ends also appears to help wet weather performance.*

After being sidetracked by the element end effect investigation, it was decided that an additional 1/8 inch (3.2 mm) would be added to the length of all the elements. This would move the gain peak down to 436 MHz. This tuning makes the gain at 432 MHz approximately 0.1 dB lower than the maximum at 436 MHz — the most desired frequency to which the antenna would be tuned — because the pattern at 432 MHz is somewhat cleaner and mutual impedance effects from the other Yagis in arrays would not be detrimental. These mutual impedance effects tend to lower the center frequency of an array of Yagis relative to the free-space center frequency of a single Yagi.

An array of four medium-sized Yagis (RIW-19s) had both a measured and calculated frequency shift of about 600 kHz. Based on this, an array of 16 Yagis could have a frequency drop of nearly 2 MHz. *If these mutual impedance effects cause the array to move over the high frequency gain dropoff point, the array will never perform as well as expected.* In fact, it is for this reason that some Yagis can never obtain the theoretical 3-dB stacking gain. In addition, the radiation pattern of most Yagis deteriorates rapidly above the gain peak. It is for these reasons that Amateurs were not very successful in getting EME arrays made from some of the early Amateur Yagi designs to work properly.

Computer-generated patterns for the 24-element, 17-foot, 3-inch (5.2 m) and the 32-element, 24-foot (7.3 m) Yagis are given in **figs. 2** and **3**. Actual E plane pattern measurements for both Yagis are shown in **figs. 4** and **5**. A comparison with the patterns of the stock 424B (**figs. 6** and **7**) demonstrates the attention paid to improving the radiation patterns. When comparing the patterns, keep in mind that the revised Yagis use a single reflector instead of the tri-reflector on the

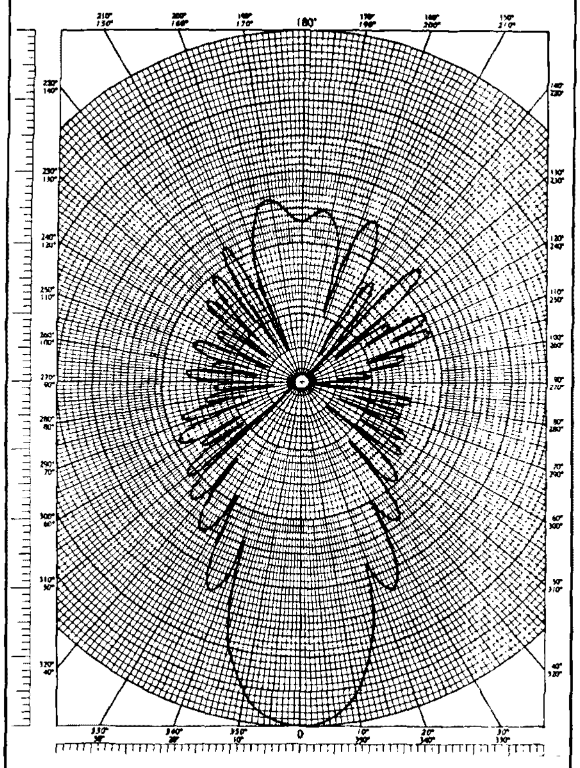


fig. 5. Measured E plane pattern of 32-element Yagi, version 2.

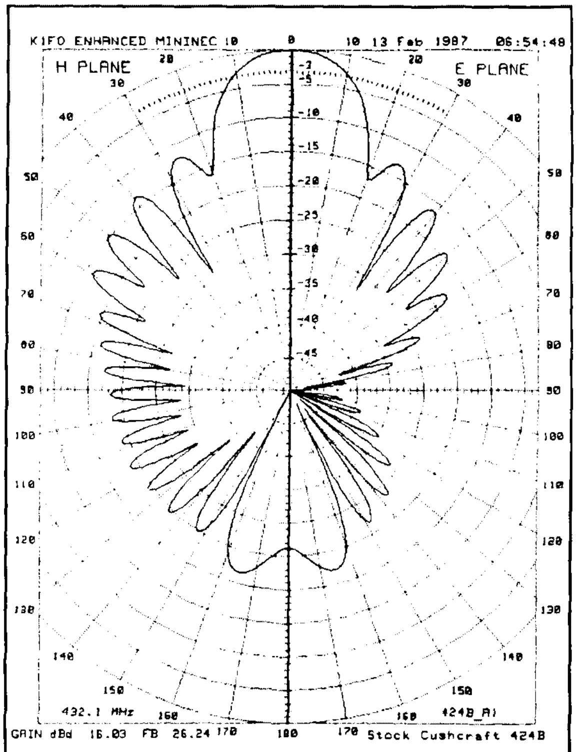


fig. 6. Calculated E and H plane pattern for unmodified 424B Yagi.

original antenna. The calculated gain-versus-frequency plots (**fig. 8**) provide more interesting data. The maximum gain point of the modified Yagis has been moved 4 MHz higher, to 436 MHz. In addition, the high-side gain cliff, the point at which the gain of the Yagi rapidly drops off, is moved almost 8 MHz higher in frequency. A smooth gain-versus-frequency curve is an indication that the directors are operating in a synergistic mode and hence at or near their maximum possible performance.

Between the 24- and 32-element versions of the Yagis, eight different test Yagis were built before the published dimensions were selected. There's still room for a little improvement in the 32-element Yagi; this will be covered in more detail later.

It's obvious that with the accuracy of antenna analysis programs available to most Amateurs, an important post-computer optimization process is required. One shouldn't put too much confidence in any analysis program until the results have been confirmed with real antennas. With the help of the more sophisticated method of moments analysis programs, I now need only one or two tries building a real antenna to get it right. Getting to this point required two years of learning both the limitations of the programs I use and more about the design of Yagis.

design procedure

The design cycle is still an iterative process. It first uses a rough optimization using WB3BGU's computer program. Next, the results of the YAGI program are confirmed by a more sophisticated but vastly slower method of moments program. If the design is believable, a test Yagi is made and measured at this point. From that data, further computer tuning is done and other test antennas are made. **Figure 9** shows the flow chart for the computer-aided Yagi design process.

The calculated patterns were done on an enhanced version of MININEC. This program's results appear to have gain figures and calculated patterns that more closely represent the real world than those generated by the YAGI program. It should be noted that the calculated gain figures are slightly optimistic because they do not account for balun and element resistive losses, mechanical tolerances, or unwanted radiation from the feed. Likewise, the calculated patterns are also optimistic for the same reasons. One may expect that the real Yagi's sidelobes will be 1 to 2 dB poorer than calculated, with the main lobe slightly narrower than

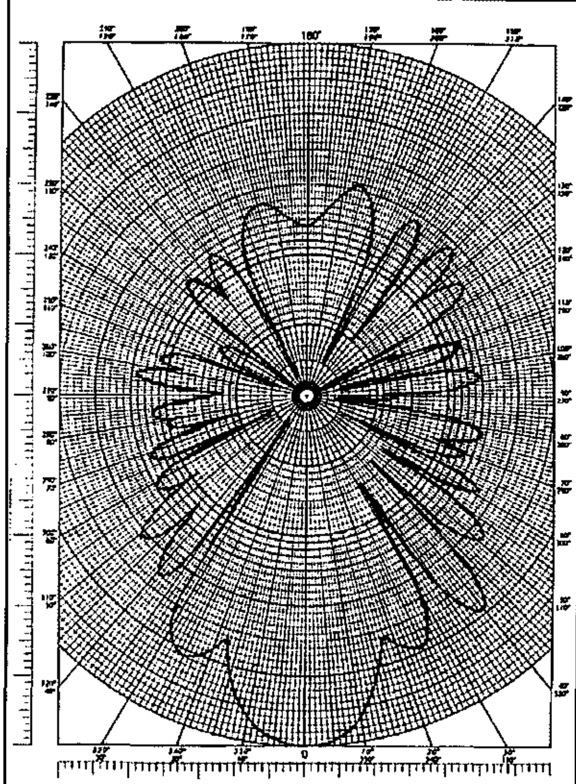


fig. 7. Measured E plane pattern for unmodified 424B Yagi.

calculated and gain typically 0.1 dB lower than calculated.

Careful comparative gain measurements between these Yagis and both the RIW-19 Yagi (14.9 dBd) and the KLM 432-30-LBX Yagi (17.3 dBd) indicate that the 32-element version 2 Yagi has 17.7 dBd forward gain and the 24-element model has about 16.4 dBd gain, or 0.5 dB over the original 424B. Computer analysis by both the WB3BGU program and the more sophisticated method of moments programs agrees with these gain comparisons. As a reference, a 31-element, 24-foot (7.3 m) DL6WU design Yagi measures 17.5 dBd and has a slightly poorer pattern. The optimized 31-element DL6WU design for which I calculated the revised element lengths has a slightly better pattern than the 32-element version 2 Yagi, but lower gain at 17.6 dBd.[7] The improved 32-element design (version 3) theoretically has as good an overall pattern as the optimized DL6WU design, but with almost 0.2 dB higher forward gain. Accuracy of these gain figures should be within 0.2 dB.

I believe that the maximum theoretical gain that can be obtained with a 17-foot (5.2 m) 432-MHz Yagi is 16.6 dBd and that the maximum for a 24-foot (7.3 m)

Yagi is 18.0 dBd. Thus, these Yagis are near the theoretical maximum possible gain, given their boomlengths. Further performance increases would require radical changes in element spacings, and therefore defeat the objective of devising an improved antenna that was easy to build from an existing commercial model. These theoretical gain improvements are also very small (approximately 0.2 dB). Keep in mind that a measured gain of 18.0 dBd for a 24-foot (7.3 m) 432-MHz Yagi may never be obtained because of resistive losses, construction tolerances, unwanted feed radiation, and feed imbalance. Although the original design objective was to create an easy-to-copy modification of a commerical Yagi, the above performance comparison indicates that the design is worthy enough to be considered for construction from scratch. This is verified by the fact that the 32-element, 24-foot (7.3 m) design has never been beaten at an antenna gain contest by a similar size Yagi. The only Yagi ever to exceed its gain at an antenna contest was almost 29 feet (8.8 meters) long, which is 5 feet (1.5 meters) longer in boomlength.

Table 1. Dimensions for a 24-element Yagi, version 3.

Spacing	Length	Boom (inches)	
1.000,	13.6250	1	REF
5.250,	13.2500	1	DE
7.875,	12.6250	1	D1
11.563,	12.2500	1	D2
16.813,	12.1875	1	D3
23.563,	12.0625	1	D4
31.875,	11.8750	1	D5
42.125,	11.6875	1	D6
52.375,	11.5625	1	D7
62.625,	11.3750	1	D8
72.875,	11.3125	1 1/8	D9
83.125,	11.2500	1 1/8	D10
93.375,	11.1875	1 1/8	D11
103.625,	11.1250	1 1/8	D12
113.875	11.0625	1 1/8	D13
124.125,	11.0000	1 1/8	D14
134.375	11.0000	1 1/8	D15
144.625,	10.9375	1	D16
154.875,	10.8750	1	D17
165.125,	10.8750	1	D18
175.375,	10.8125	1	D19
185.625,	10.8125	1	D20
195.875,	10.7500	1	D21
206.125,	10.7500	1	D22

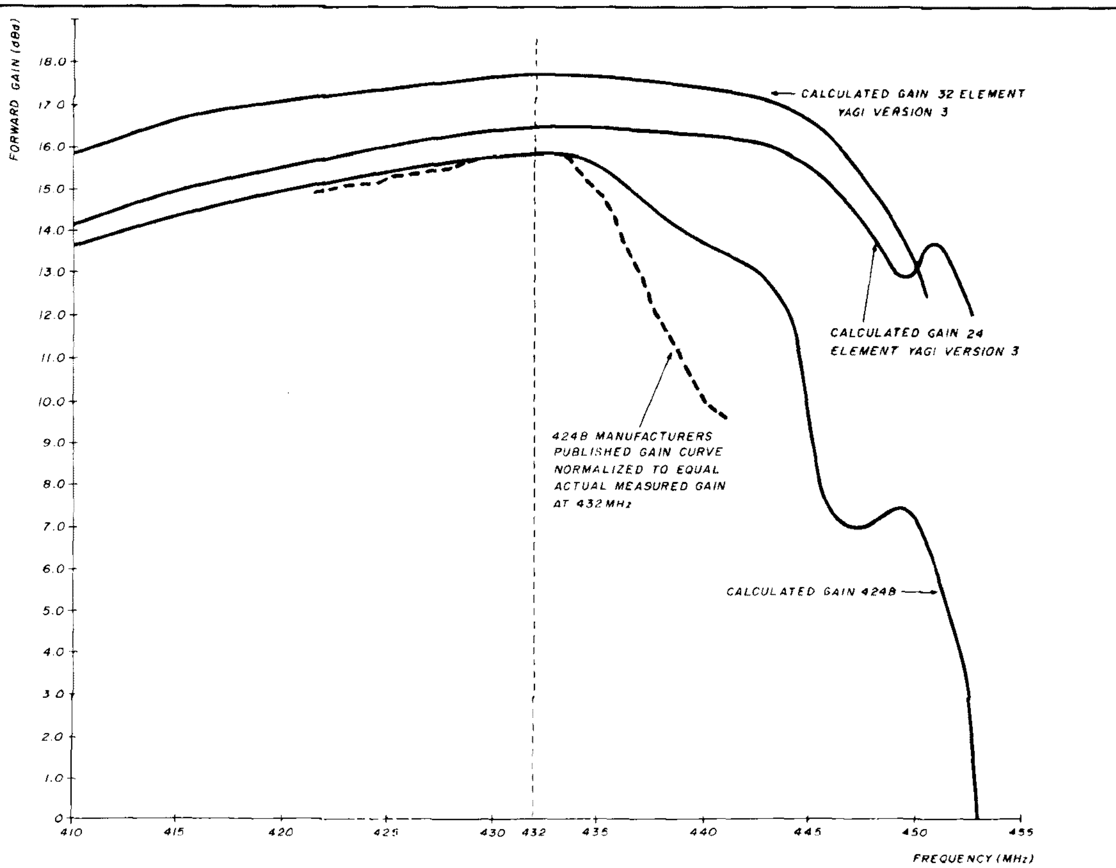


fig. 8. Calculated gain versus frequency is higher than actual gain, since 100 percent power transfer is assumed at all frequencies — i.e., feed impedance changes are ignored.

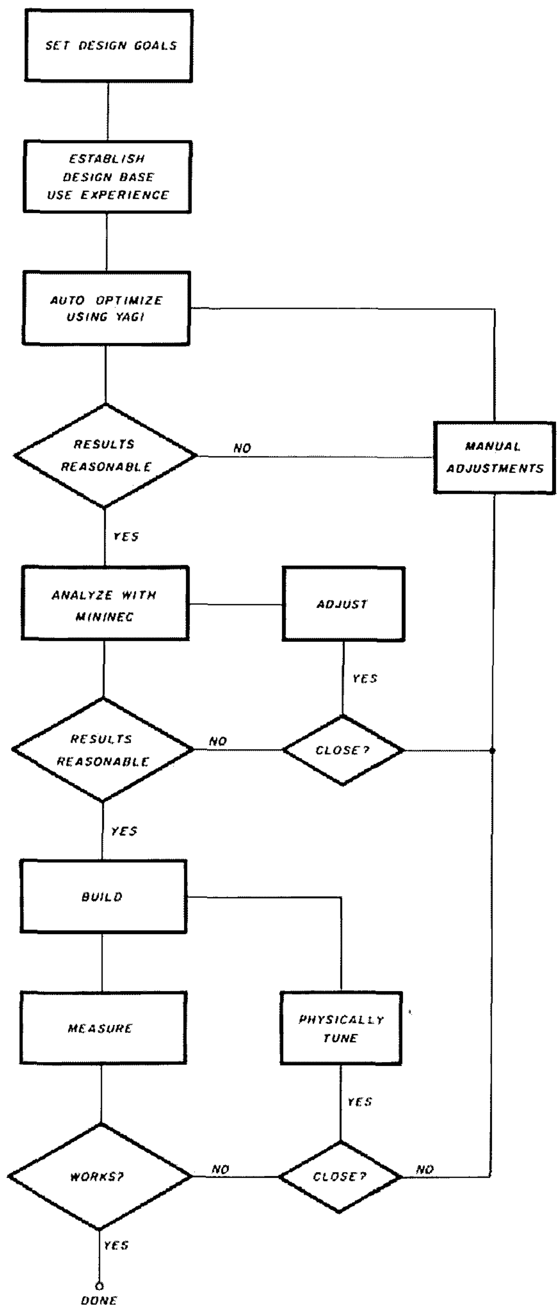


fig. 9. Computer-aided Yagi design cycle.

construction

The actual construction of either of these Yagis starts with the drilling of three new element holes in the boom. The driven element is mounted in a new hole 2.625 inches (66.7 mm) behind the original driv-

en element hole. The old DE location now becomes director 1 and the original director 1 is now director 2. A second new hole is drilled for director 3. The original director 2 hole is no longer used and a final new element hole is added between the original director 2 and 3 holes where a new director 4 now goes. This provides a new antenna with 24 elements — the same number as the original 424B.

The improved Yagis use a single reflector instead of the 424B's tri-reflector. Thus two additional close-spaced directors are added in the new design. A new hole for the N connector bracket is drilled 2.625 inches (66.7 mm) behind the original. The hole for the balun clamp is moved 3.125 inches (79 mm) further back to accommodate the shortened baluns used on the modified Yagis. **Figure 10** shows the new hole drilling pattern for the rear boom section. This revised element spacing is common to both the 24-element and 32-element versions.

Constructing a 24-element Yagi from an unassembled 424B requires only 27 inches (0.69 m) of 3/16-inch aluminum rod and 2 inches (5 cm) of No. 12 copper wire. Modifying an assembled 424B requires the same parts plus a number of element retainers to replace those which will be destroyed in disassembly. One should note that most of the directors could be filed down while in place on the boom, provided that one was careful in checking dimensions during the filing process. It's easier, however, if the element lengths are checked carefully when they're removed from the Yagi. Cutting tolerance should be kept within ± 1/32 inch (0.8 mm). for reassembly of an existing 424B, suitable stainless steel element retainers (No. 6100-18) made by Industrial Retaining Ring Company of Irvington, New Jersey, can be ordered from most local industrial hardware distributors. Suitable retainers can also be ordered from Cushcraft.

Table 1 is a list of the dimensions for the new element lengths of the 24-element Yagi. There are few common dimensions with the original 424B. No attempt was made to save existing element lengths.

The listed dimensions are for version 3 of the 24-element Yagi; they supersede any information I distributed before August, 1986. The version 3 Yagi incorporates additional element adjustments which were modeled on MININEC and confirmed on a test antenna. The latest version features improvements in both gain and pattern. Be sure to put a slight chamfer on the end of the elements — otherwise the antenna will tune lower in frequency and the driven element match may not be acceptable.

The driven element is described in **fig. 11**. Note that the rectangular black spacer insulators used between the driven element and T match bars are no longer used. The No. 16 wire used to connect the T match to the N connector is replaced by a No. 12 wire. This was done both to improve the VSWR bandwidth and reduce unwanted radiation from the jumper wire. Measurement of a stock 424B gave a VSWR of 1.15:1 when dry and over 10:1 when doused with water from a garden hose. The revised match arrangement on the modified Yagi has a VSWR less than 1.12:1 when dry and about 2.0:1 (measured at the feed) when drenched with water.

When radiation patterns were first made on the modified Yagis, an imbalance in the sidelobes was noted. A similar pattern distortion was also measured on a stock 424B. Several more measurements were made to determine whether the pattern distortions were occurring in the measurement method or were actually in the Yagis. To confirm that the imbalance was really in the antenna, the test 424B was flipped over. The pattern imbalance changed sides when the Yagi was turned over. This indicated that the pattern distortion was in the antenna and not attributable to range reflections.

After checking a number of possible causes for the imbalance, it was determined that the balun on the 424B was 1.00 inch (25.4 mm) too long. A length error of exactly 1.00 inch (25.4 mm) leads me to believe that the error in balun length was due to a simple number translation mistake when the 424B's designer calculated the balun length, and that it wasn't made that length intentionally. The main objective of a half-wavelength balun is to provide a 180-degree phase shift to feed the other half of the drive element. The actual length of the balun should be 180 electrical degrees, including the ends of the balun that protrude from the shield. One should not change the length of the balun to obtain a good match; this will cause pattern distortion. The shorter balun also appears to help the wet weather VSWR. If you don't shorten the balun, the driven element dimensions will be different for a proper match.

designing (and mounting) a longer Yagi

The success of the 24-element, 17-foot (5.2 m) Yagi inspired a longer version. The design objective of the long Yagi was simply to outperform any available commercial or homemade Yagi. The appearance of the 22-foot (6.7 m) KLM 432-30-LBX, based upon the DL6WU design (with 17.3 dBd gain), plus the increasing use of homemade DL6WU Yagis up to 24 feet (7.3 meters) long, added to the challenge. A secondary design objective of the longer version was to make it from readily available parts.

A 24-foot (7.3 m) length was selected because I believed it to be a practical size limit, so the Yagi would be reasonably easy to handle. While longer Yagis may appear practical on paper, the construction of an EME array, which requires elevation movement, places

Table 2. Dimensions for a 32-element Yagi, version 2.

Spacing	Length	Boom (inches)	
1.000,	13.9375	1	REF
5.250,	12.8750	1	DE
7.875,	12.9375	1	D1
11.563,	12.3750	1	D2
16.813,	12.3750	1	D3
23.563,	12.2500	1	D4
31.875,	12.0625	1	D5
42.125,	11.8750	1	D6
52.375,	11.7500	1	D7
62.625,	11.5625	1	D8
72.875,	11.3750	1 1/8	D9
83.125,	11.3750	1 1/8	D10
93.375,	11.3750	1 1/8	D11
103.625,	11.3125	1 1/8	D12
113.875,	11.0625	1 1/8	D13
124.125,	11.0625	1 1/8	D14
134.375,	11.1250	1 1/4	D15
144.625,	11.1250	1 1/4	D16
154.875,	10.9375	1 1/8	D17
165.125,	10.9375	1 1/8	D18
175.375,	10.9375	1 1/8	D19
185.625,	11.0000	1 1/8	D20
195.875,	10.9375	1 1/8	D21
206.125,	10.9375	1 1/8	D22
216.375,	10.8125	1 1/8	D23
226.625,	10.8125	1	D24
236.875,	10.8125	1	D25
247.125,	10.8125	1	D26
257.375,	10.8125	1	D27
267.625,	10.8750	1	D28
277.875,	10.8750	1	D29
288.125,	10.8125	1	D30

Table 3. Dimensions for a 32-element Yagi, version 3 (not tested).

Spacing	Length	Boom (inches)	
1.000,	13.6250	1	REF
5.250,	12.9375	1	DE
7.875,	12.7500	1	D1
11.563,	12.3125	1	D2
16.813,	12.3125	1	D3
23.563,	12.1875	1	D4
31.875,	12.0000	1	D5
42.125,	11.8125	1	D6
52.375,	11.6875	1	D7
62.625,	11.5000	1	D8
72.875,	11.3438	1 1/8	D9
83.125,	11.3438	1 1/8	D10
93.375,	11.3438	1 1/8	D11
103.625,	11.2813	1 1/8	D12
113.875,	11.0938	1 1/8	D13
124.125,	11.0313	1 1/8	D14
134.375,	11.0625	1 1/4	D15
144.625,	11.0000	1 1/4	D16
154.875,	10.9688	1 1/8	D17
165.125,	10.9688	1 1/8	D18
175.375,	10.9063	1 1/8	D19
185.625,	10.9063	1 1/8	D20
195.875,	10.9063	1 1/8	D21
206.125,	10.8438	1 1/8	D22
216.375,	10.8438	1 1/8	D23
226.625,	10.8125	1	D24
236.875,	10.7500	1	D25
247.125,	10.7500	1	D26
257.375,	10.7500	1	D27
267.625,	10.7500	1	D28
277.875,	10.6875	1	D29
288.125,	10.6875	1	D30

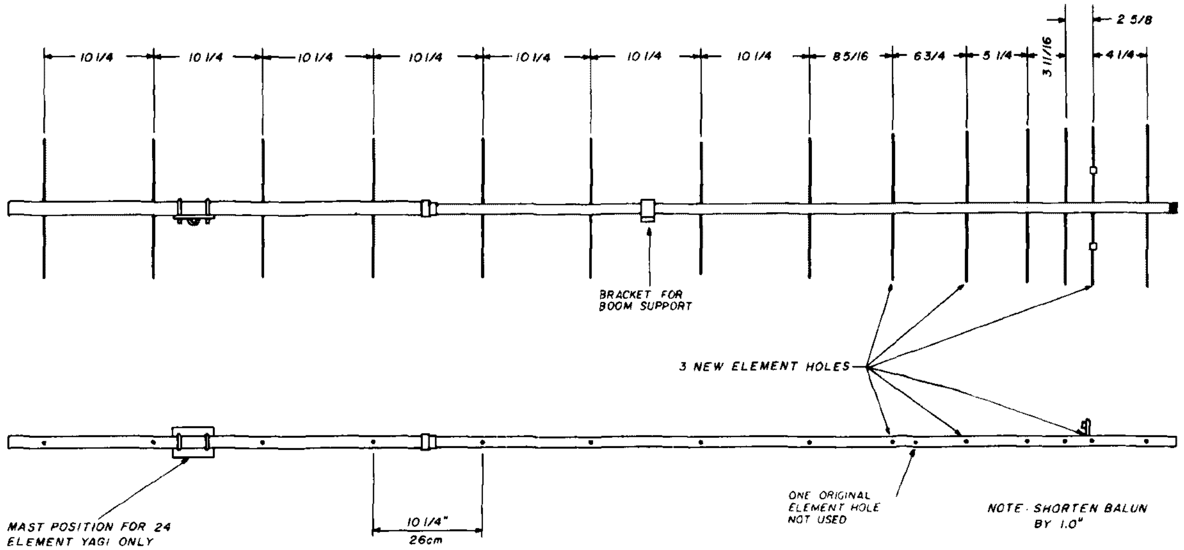


fig. 10. New spacing pattern for 24, 32, and 38-element Yagi.

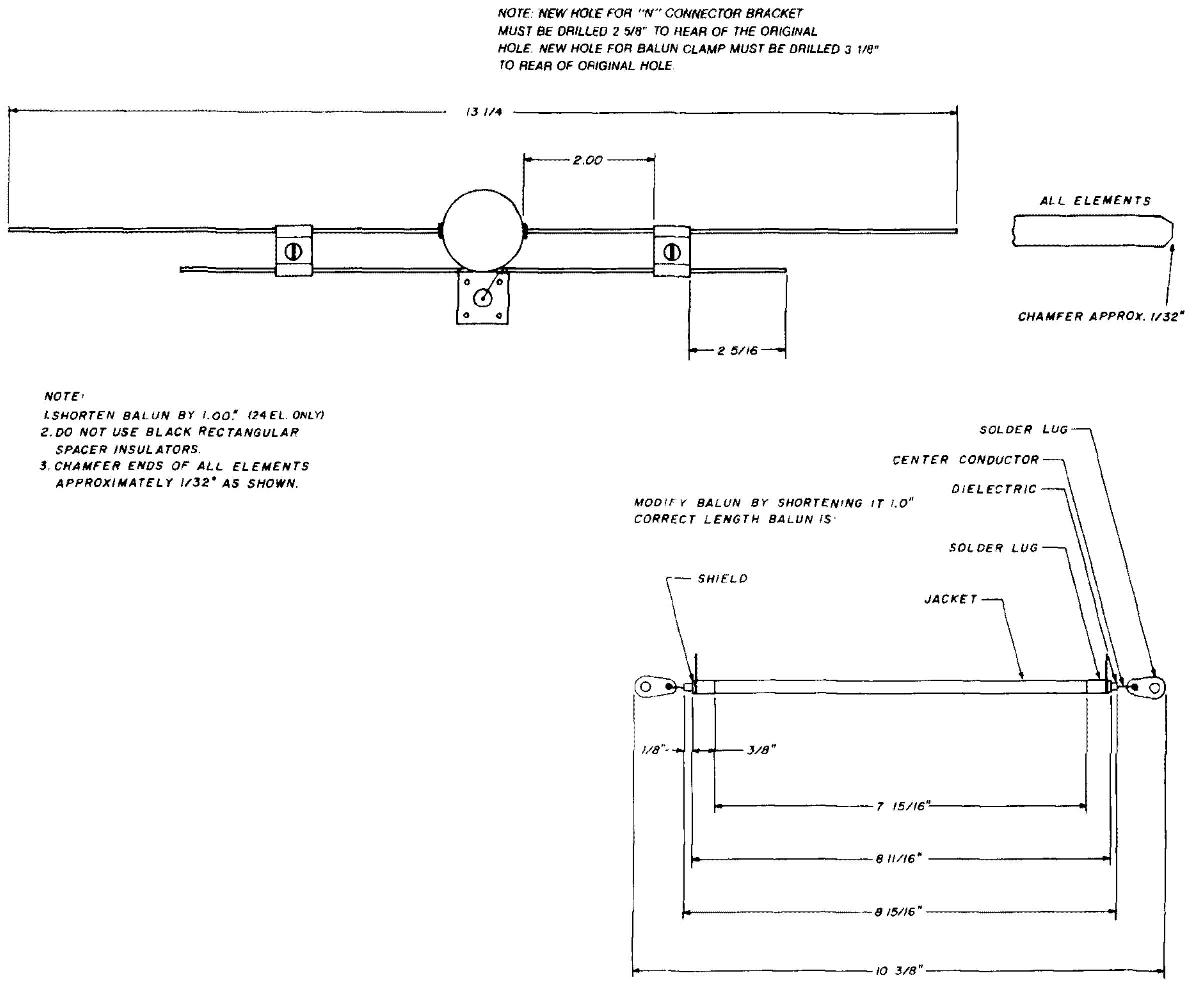


fig. 11. Driven element details for the 24-element Yagi. Note balun details.

additional demands on the supporting tower. Typical EME arrays are mounted about 20 feet (6.1 meters) above the ground; an array of 16 of the 24-foot (7.3 meters) long Yagis has only 4 feet (1.2 meters) of ground clearance when tilted back. Longer Yagis will need a higher tower and hence one that is considerably stronger than the commonly used Rohn 45. If an array of such long Yagis is intended to be mounted atop a tall guyed tower, for use on tropo, for example, the design becomes more difficult. An array made from even longer Yagis would have to be mounted a large distance above the top guy wires in order to allow elevation movement. In the case of an array made from 24-foot (7.3 meters) Yagis, the height above the guys is 14 feet (4.3 meters). An array made from eight of the Yagis stacked two wide and four high has a total windswept area of over 40 square feet when phasing lines, preamplifier enclosure, and all other required accessories are included. Such an array presents a loading force that is at the limit of what a Rohn 55 can handle. When one considers that an array of eight 29-foot (8.8-meter) Yagis has a wind area approaching 50 square feet and would have to be mounted over 16 feet (4.9 meters) above the guys, one can see how quickly the tower loading can get out of hand.

The 24-foot (7.3-meter) length worked out well because it could be obtained by purchasing an additional center boom section for the 424B from Cushcraft. The availability of the additional boom section, in pre-drilled form, sealed the design length. To complete the boom only a simple, short, 1-1/4 inch (38 mm) OD, 0.058-inch (1.5 mm) wall, 6061-T6 aluminum tube splice was required.

Those who build the Yagi may note that it could have been made with an additional director (10.25 inches/260 mm longer). I decided to keep the anten-

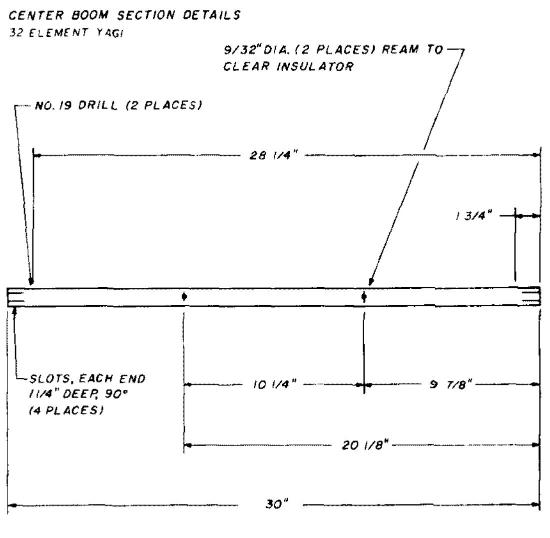


fig. 12. Center boom section details.

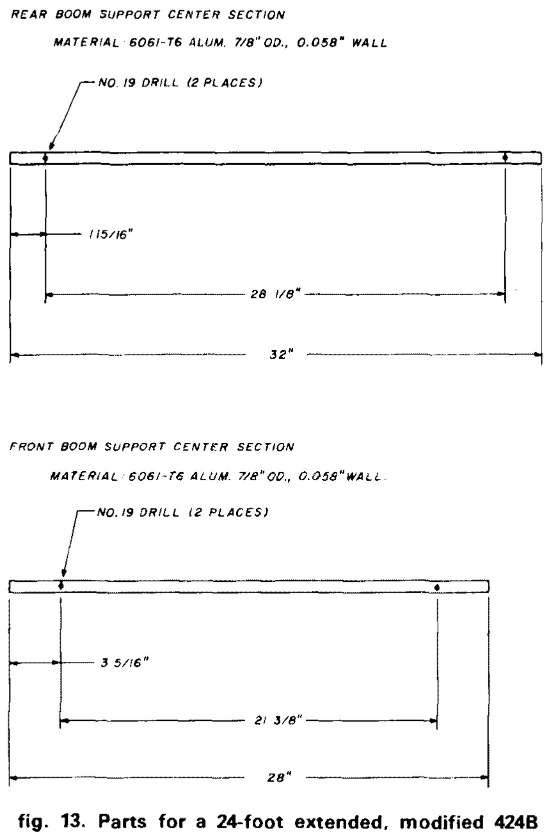


fig. 13. Parts for a 24-foot extended, modified 424B antenna.

na at 32 elements and overlap the rear and center boom sections for additional strength. The selected length and mast mounting position creates a balanced antenna when a feedline is attached. Having a balanced antenna is an important consideration, especially when it will be used in large arrays. The center boom piece is detailed in **fig. 12**.

The longer, 24-foot (7.3-meter) length made the original Cushcraft 424B boom support inadequate. A solution was again found in Cushcraft parts. A new boom support was made from preformed boom support pieces for the 220B antenna. This required only the fabrication of two simple straight splice sections of 3/4-inch (19-mm) OD, 0.058-inch (1.5-mm) wall aluminum tube. The new boom support center pieces are described in **fig. 13**.

Alternately, one can make one's own boom supports. Another possibility would be to lengthen the original 424B supports by using 0.625-inch OD, 0.058-inch wall aluminum tubing. Since the parts for the new boom support were purchased, Cushcraft changed the design of its boom supports. Suitable boom supports can now also be made from the supports used on either the latest A32-19 or 4218-XL 144-MHz Yagis. A rigid boom support is preferable to a simple support wire; it adds lateral strength to the boom, minimizing oscillation in the wind.

Element lengths for the 32-element version 2 Yagi are given in **table 2**. These are the latest tested dimensions and are representative of the version that's been brought to several antenna contests and also used in NC1I's EME array. The director lengths, which don't get progressively shorter, may not seem logical, but I found that this length arrangement was necessary to keep an acceptable pattern, given the closer-than-desired director spacing used in the 424B boom sections.

Since the version 2, 32-element Yagi was perfected, access to more sophisticated computer programs has allowed an improved director string to be calculated. The new director arrangement uses an element length scheme similar to the version 3, 24-element Yagi. That is to say, all directors are shorter than the preceding one. This new director string theoretically has 0.1 dB more gain than the version 2 arrangement. The pattern is also slightly cleaner, in theory. Dimensions for the new arrangement called version 3 are given in **table 3**. These dimensions haven't been confirmed by the construction and measurement of test antennas. Experience with the version 3, 24-element Yagi makes me confident that the revised 32-element design will perform as predicted. One can never be completely certain that it will perform as expected until a real antenna is built and measured. The design data for all of these Yagis is presented here because publishing my work up to this point was long overdue. One

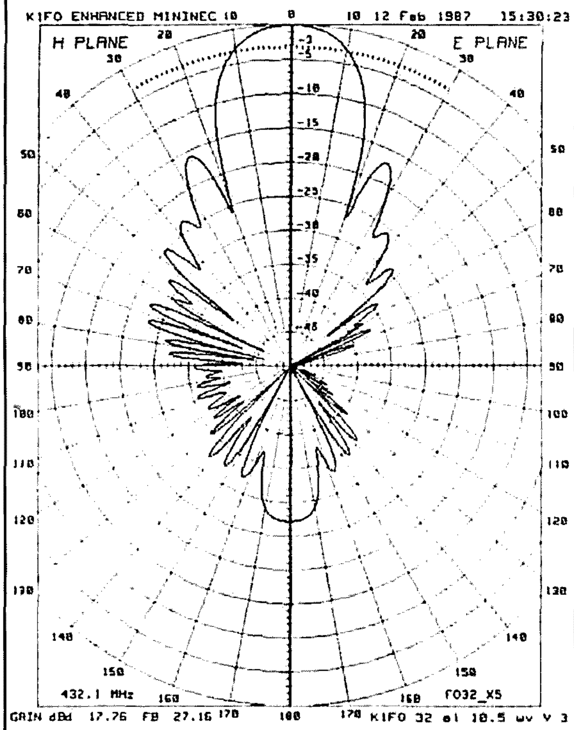


fig. 14. Calculated E and H plane patterns for a 32-element Yagi, version 3.

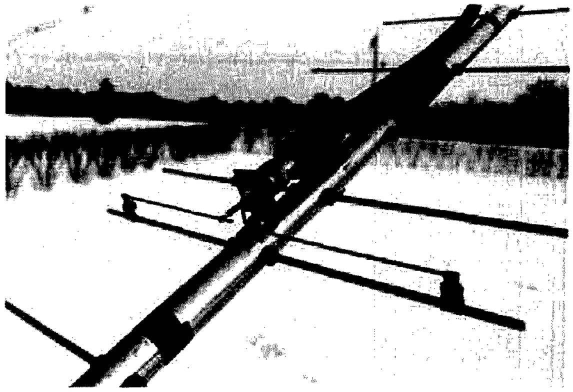


Photo A. Thirty-two element Yagi driven element.

could become consumed in a lifetime project to continually improve upon the last design. If such a cycle were to continue forever — without publishing any of the earlier work — there would be no benefit to the Amateur community. However, be forwarned that if you decide to build a Yagi using the **table 3** dimensions, you'll be entering uncharted territory. Calculated E and H plane patterns for the version 3 Yagi are given in **fig. 14.**

The maximum performance objective for the 24-foot (7.3-meter) Yagi also required a new driven element construction. I felt that the 424B-based driven element had excessive, unwanted radiation from the

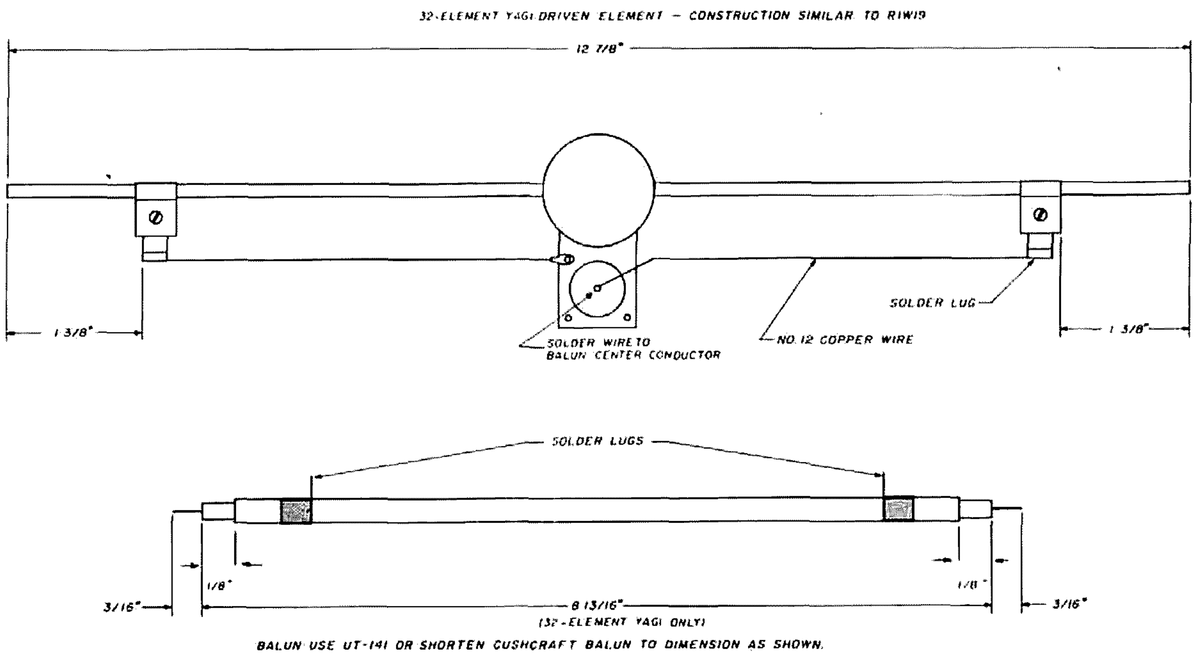


fig. 15. Driven element and balun details for a 32-element, 24-foot, 432-MHz Yagi.

wire between the N connector and T match bars. To remedy this situation, a driven element patterned after that used on the RIW Products 19-element 432-MHz Yagi was made, moving the N connector closer to the boom. This has been done both by cutting down the Cushcraft-supplied connector brackets and also by making copies of the brackets employed on RIW Products' Yagis. The new T match uses No. 12 copper wires, as does the RIW Yagi. A UT-141 balun was used, replacing the Cushcraft RG-303 balun. The Yagi with the new T match appears to have close to 0.1 dB more gain than one with the modified Cushcraft match. Either match can be used on either version of the antenna. The builder will have to decide if the less than 0.1 dB gain increase is worth the added effort. Those perfectionists in the audience may note that the UT-141 balun accounts for about 0.05-dB loss. A larger size copper hardline such as UT-225 or a sleeve balun could be fabricated if one finds that loss upsetting. Construction details of the new T match for the 32-element Yagi can be found in **fig. 15** (see

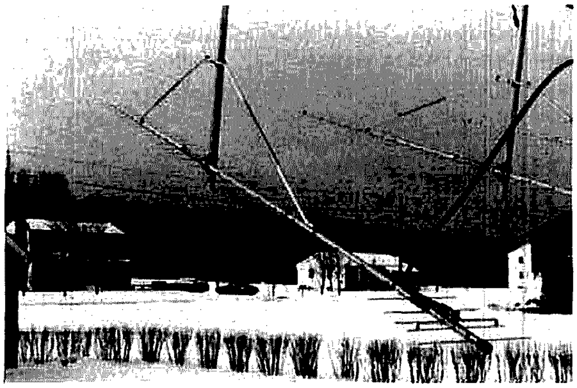


Photo B. Thirty-two element, 24 foot Yagi.

Photo A). The boom layout for the 32-element Yagi is shown in **fig. 16** and **Photo B**.

There are sure to be some operators who won't be satisfied with a 24-foot Yagi. For those adventurous souls, element lengths for a 38-element, 29-foot version (see **fig. 17**) are given in table 4. The expected gain of this 38-element model is 18.5 dBd. If you attempt to build the 38-element version, please keep in mind that because I haven't built or tested this version, I won't be able to give advice on the construction of a driven element for it or assist in debugging it. As with the improved 32-element Yagi listed in table **3**, there is a possibility that the calculated dimensions won't work as expected. Other length versions are also possible.

Any of the presented designs can be used in the OSCAR, ATV, and fm portions of the band. For use in the satellite portion of the band, a 1/16-inch shortening of the elements is desirable, but not really necessary. For use on ATV, shorten all elements by 1/4 inch (6.4 mm). The Yagi will still be usable at 432 MHz, but will have about 0.2 dB lower forward gain. To use the Yagis in the fm portion of the band, shorten all elements by 7/16 inch. If the Yagis are to be mounted vertically polarized, they should be used in pairs with a boom support placed in the middle of the pair of Yagis (**fig. 18**). The driven element T match will have to be readjusted for best VSWR if the elements are shortened.

stacking considerations

Optimum stacking distances for the best array gain versus array temperature have been worked out for the antennas. The 24-element, 17-foot (5.3-meter) Yagi should be spaced 70 inches (1.78 meters) in the E plane (horizontal) and 66 inches (1.68 meters) in the H plane (vertical). The 32-element, 24-foot (7.3-meter) version 2 antenna works best with 81-inch (2.06-meter)

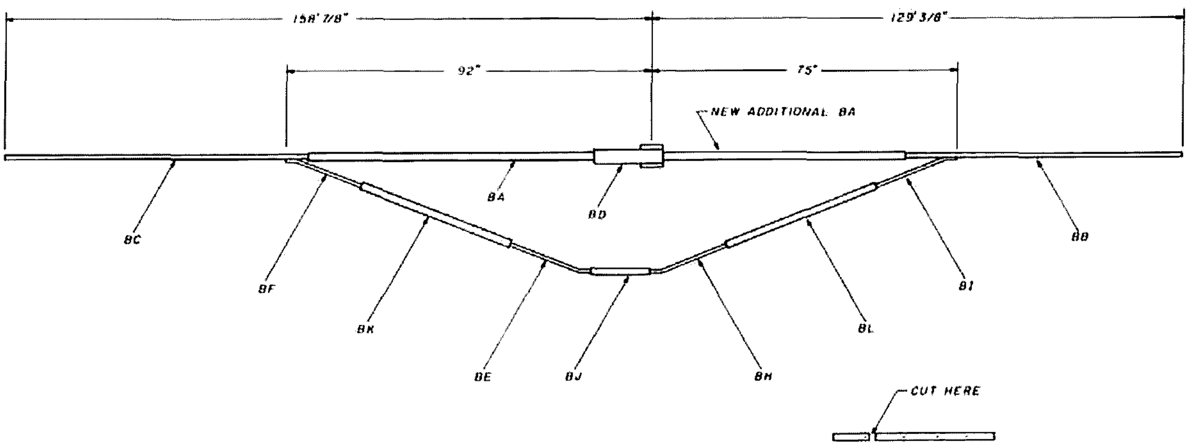


fig. 16. Boom assembly for 32-element Yagi.

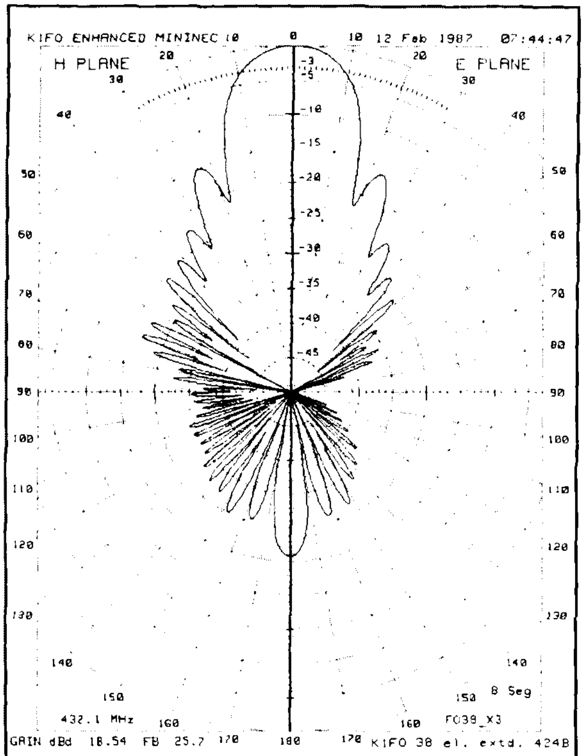


fig. 17. Calculated E and H plane patterns for 38-element Yagi.

E plane and 75-inch (1.91-meter) H plane spacing. These relatively wide spacings also confirm both the high gain and pattern cleanliness of the new Yagis. Calculated optimum spacings for the 32-element version 3 Yagis are 82-inch (2.08-meter) E plane by 77-inch (1.95-meter) H plane. For the 38-element Yagi, the calculated stacking distances are 88-inch (2.25-meter) E plane by 83-inch (2.11-meter) H plane. At these spacings, both E and H plane stacking gains will be close to 2.9 dB (negating phasing line losses and mechanical errors.)

when modification is worthwhile

Before you decide to tear down and modify your existing 424B's, you should carefully consider the results. A casual tropo operator using a single Yagi may be hard pressed to tell any forward gain difference between the stock and modified 24-element Yagi. The only noticeable differences will be in the pattern (signals off the main lobe will be weaker) and the better wet weather performance. Certainly most Amateurs aren't capable of detecting 0.5-dB gain variations. For an EME operator using eight or 16 Yagis, changing to even the modified 24-element version will result in significant improvement. On EME receive, it's expected that an eight-Yagi array will have about a 3-dB

Table 4. Dimensions for a 38-element Yagi (not tested).

Spacing	Length	Boom (inches)	
1.000,	13.6875	1	REF
5.250,	12.9375	1	DE
7.875,	12.7500	1	D1
11.563,	12.3750	1	D2
16.813,	12.3750	1	D3
23.563,	12.2500	1	D4
31.875,	12.0625	1	D5
42.125,	11.8750	1	D6
52.375,	11.7500	1	D7
62.625,	11.5625	1	D8
72.875,	11.4063	1 1/8	D9
83.125,	11.4063	1 1/8	D10
93.375,	11.4063	1 1/8	D11
103.625,	11.3438	1 1/8	D12
113.875,	11.2813	1 1/8	D13
124.125,	11.0938	1 1/8	D14
134.375,	11.0938	1 1/8	D15
144.625,	11.0625	1 1/4	D16
154.875,	11.0625	1 1/4	D17
165.125,	11.0625	1 1/4	D18
175.375,	11.0000	1 1/4	D19
185.625,	11.0000	1 1/4	D20
195.875,	11.0000	1 1/4	D21
206.125,	10.9375	1 1/4	D22
216.375,	10.9063	1 1/8	D23
226.625,	10.9063	1 1/8	D24
236.875,	10.8438	1 1/8	D25
247.125,	10.8438	1 1/8	D26
257.375,	10.8438	1 1/8	D27
267.625,	10.8438	1 1/8	D28
277.875,	10.7813	1 1/8	D29
288.125,	10.7500	1	D30
298.375,	10.7500	1	D31
308.625,	10.6875	1	D32
318.875,	10.6875	1	D33
329.125,	10.6875	1	D34
339.375,	10.6250	1	D35
349.625,	10.6250	1	D36

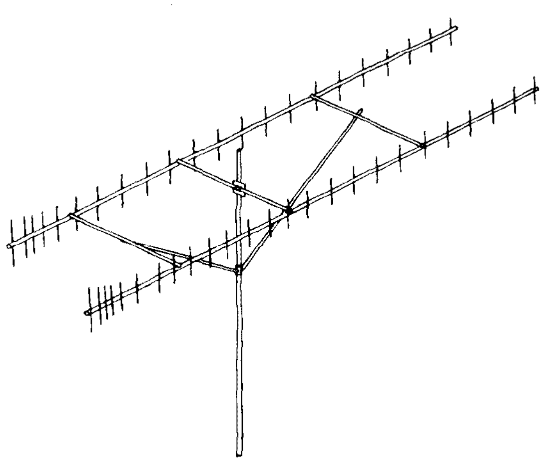


fig. 18. Recommended method of mounting a pair of vertically polarized Yagis.

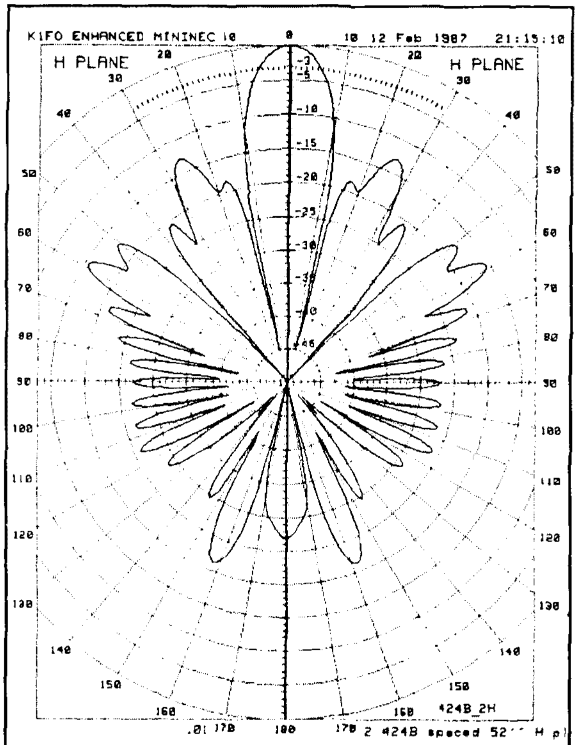


fig. 19. H Plane pattern of a pair of unmodified 424Bs spaced 52 inches apart (H plane). The total array gain is 18.50 dBd.

signal-to-noise improvement with the modified 24-element Yagis. This improvement is attributable to the following: +0.5 dB individual Yagi gain advantage; +1.0 dB higher array gain from wider optimum G/T spacings; +0.5 to 1.5 dB S/N due to lower array temperature from the cleaner array pattern.

On transmit, the gain advantage will be 1.5 dB because only the higher Yagi gain and wider spacings in the array contribute to the improvement. The signal-to-noise improvement is highly dependent upon the total receive system noise temperature. This is a combination of both the system noise figure and total phasing line loss. The actual S/N improvement could be from 0.5 dB to over 1.5 dB, depending upon the loss in the phasing lines and how low a noise figure the preamp has.

importance of clean patterns

In order to understand why a clean pattern on the individual Yagis is important, a computed H plane array pattern for two stock 424B's spaced at 52 inches is given in **fig. 19**. For comparison, the pattern for two of the modified 24-element Yagis, spaced 66 inches in the H plane, is given in **fig. 20**. Note that even at the significantly wider spacing, the array pattern of

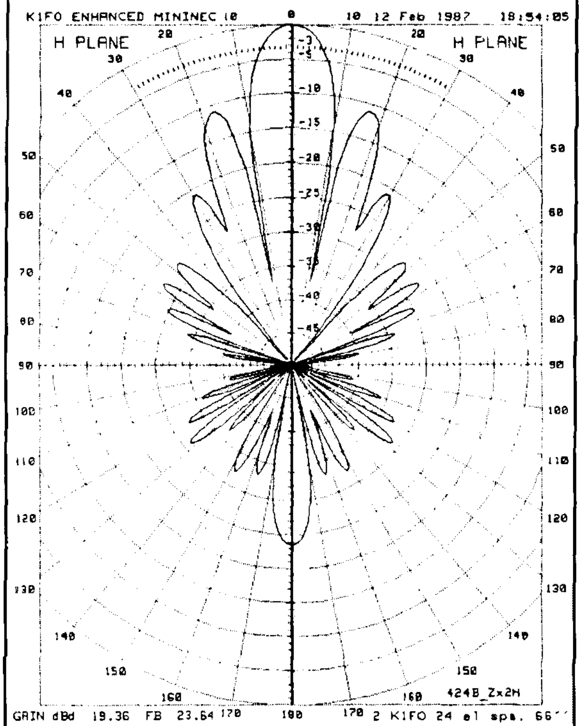


fig. 20. H plane pattern of a pair of modified 24-element Yagis spaced 66 inches apart (H plane). The total array gain is 19.4 dBd.

the modified Yagis is significantly cleaner than the original. At 432 MHz there is approximately a 15-dB difference between cold sky noise and Earth noise. Total Earth noise pickup will be a sum total of all sidelobes pointing into the Earth. This large difference in noise is why clean patterns are so important on 432-MHz EME arrays.

Although not an even comparison, it's informative to relate the experience of NC1I (ex-WA1RWU.) Frank had an array of 16 stock 424B's for 432-MHz EME. The array was rebuilt using 16 of the extended modified Yagis (32-element, 24-foot version). The results of the array rebuild are nothing short of spectacular. The receive improvement is far greater than the 1.8 dB extra gain the 24-foot (7.3-meter) Yagi has over the stock 17-foot (5.2-meter) antenna. Receive signals appear to be 5 to 6 dB above the old array, and echos are nearly 10 dB better. SSB speaker quality echos are frequently obtained with 100 watts output in the shack (approximately 80 watts at the array). Stations running four medium-sized Yagis such as the RIW-19s or F9FT-21s and 500 watts are readily workable.

A more even comparison is given by WA3FFC. Scott used an array of four stock 424B's on EME. Upon switching to the modified 24-element, same boomlength Yagis, his Sun noise increased by 1.5 dB. Cold sky areas became much easier to find. Copy of his own echos was never obtained with the stock Yagis. With the modified 24-element versions, his echos are now regularly copied. Random EME QSOs are now possible with the modified array.

To further expound on how the state of four Yagi 432-MHz EME has evolved, consider the results of a recent portable EME expedition to Vermont by NC1I. Frank took four of the 32-element Yagis to Vermont in the middle of June. Because of higher ionospheric absorption, greater Faraday shifts, increased tropo scattering, and longer daylight hours, the summer months are usually the poorest for 432-MHz EME. In spite of these obstacles, NC1I worked 22 stations on a single weekend. More impressive is that all QSOs were random — no prearranged schedules were used!

conclusion

With Yagi analysis software, the computer has succeeded in moving Amateurs from the dark ages of Yagi design to the point at which a well-performing Yagi can be readily made from materials at hand. The successful use of any antenna analysis program requires that the antenna designer have a thorough understanding of its capabilities and limitations.

In this project, the total design time — from the first correct running of the analysis program to completion of the initial Yagis — was over 10 months of continuous work. This time included physical tuning of the Yagis. Further improvements made to create the version 3, 24-element Yagi and version 2, 32-element Yagis were done during a year's intermittent work on the antennas. While this amount of design time may represent a high initial investment for a manufacturer of Yagi antennas, the design knowledge gained would most likely allow a similarly complex Yagi to be perfected in about one month. Continued enhancements of antenna design programs and more good Yagi designs will allow still further improvements in the quality of tomorrow's Yagis.

references

1. Günter Hoch, DL6WU, "More Gain with Yagi Antenna," *VHF Communications*, April, 1977, page 204.
2. Steve Powlishen, K1FO, "Stacking Yagis Is A Science," *ham radio*, May, 1985, page 18.
3. Stanley Jaffin, WB3BGU, "Applied Yagi Antenna Design," Part 6, *ham radio*, October, 1984, page 93.
4. Günter Hoch, DL6WU, "Yagi Antennas," *VHF Communications*, March, 1977, page 157.
5. Johann Bruinier, DL9KR, "Long Yagi Mark II," *The Lunar Letter*, December, 1983, page 6.
6. Günter Hoch, DL6WU, "Yagi Antennas," *VHF Communications*, March, 1977, page 162.
7. Joe Reisert, W1JR, "VHF/UHF World: A High-gain 70-cm Yagi," *ham radio*, December, 1986, page 75.

ham radio

build a 1-1000 MHz amplifier using MAR-4 MMICs

Simple device, many applications

During the last few years the availability of surplus test equipment has made fairly sophisticated *rf* measurements possible for hams on small budgets. Many own rf signal generators with accurate output attenuators that provide precise signal levels. Using the new microwave IC amplifiers, it's easy to build a broadband utility amplifier to serve as a handy test aid for signal generators.[1]

Broadband amplifiers are widely used — and sold in many different models — to increase the accuracy and range of rf measurements. Typical uses include the following:

- Boosting signal generator output for aligning a "numb" receiver or a badly misaligned bandpass filter.
- Increasing isolation between signal generators in multi-generator setups (as in two-tone third-order intermodulation tests).
- Regaining lost power (when attenuators are used at the test interface to ensure a proper 50-ohm impedance match).
- Increasing measurement range (to determine insertion loss of filters).

Parts information and construction details are given for making a broadband utility amplifier that covers hf through UHF with 13 dB gain and +10 dBm output. Most parts are readily available, and construction takes only a few hours.

design considerations

The amplifier IC was selected on the basis of gain and output power required. I needed at least +10 dBm output because this is the maximum power indicated by my thermistor-mount power meter. Because the signal generator output sometimes drops to 0 dBm, 10-dB gain was required. Designed around the Mini-Circuits Lab MAR-4, the amplifier and power supply are shown in **fig. 1**.[2]

Specifications of the MAR-4s are shown in **table 1**. Since the amplifiers have 50-ohm input/output impedances and are guaranteed to be stable regardless of load, the only design effort is selecting a power supply dropping resistor. I decided to sacrifice gain for simplicity and not use a series rf choke, making the resistance as large as possible. The power supply current is a substantial 50 mA, so power dissipation is a consideration. The 180-ohm resistance was selected as a maximum convenient value within the restric-

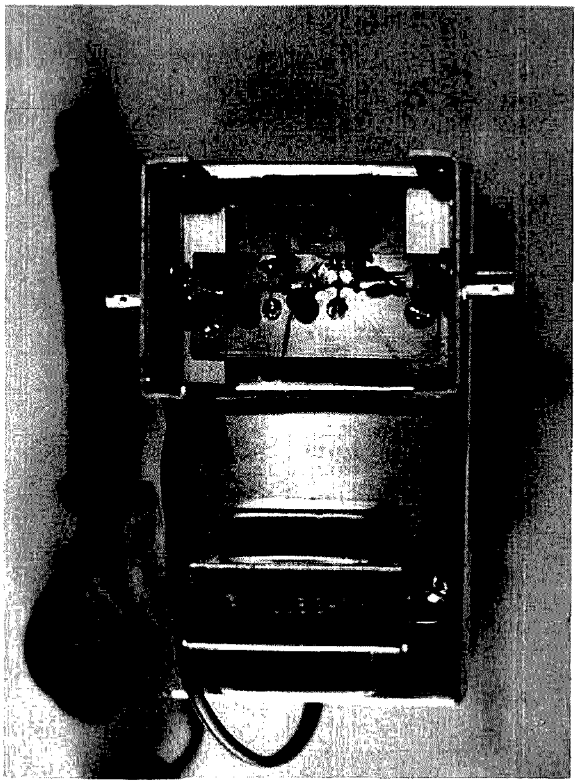
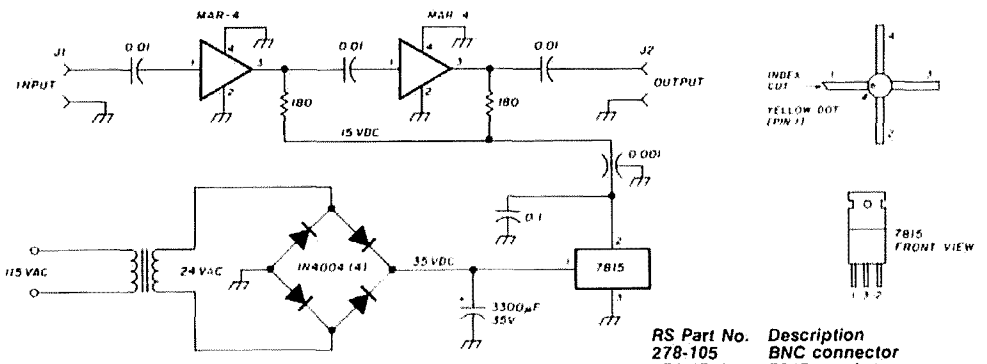


Photo A. Self contained MMIC amplifier and power supply, with mini-box cover removed.

By Cliff Klinert, WB6BIH,, 1126 Division Street, National City, California 92050



RS Part No.	Description
278-105	BNC connector
276-1772	7815 regulator
270-238	chassis box (5-1/4 x 3 x 2-1/8 inches)
270-235	chassis box (2-3/4 x 2-1/8 x 1-5/8 inches)
273-1366	transformer 24 VAC 450 mA
276-1103	diodes 1N4004

fig. 1. Complete broadband amplifier including power supply. The 0.01 and 0.1-μF capacitors are disc ceramic and the resistors 1/2-watt carbon composition.

Table 1. Specifications of Mini-Circuits Labs MAR-4 MMICs.

frequency	dc to 1000 MHz
gain	7 dB (minimum)
flatness	± 0.5 dB
output (+1 dB compression)	+11 dBm
input (no damage)	+15 dBm (maximum)
noise figure	7 dB typical
VSWR (in)	1.9:1
VSWR (out)	2.0:1
dc power	5 volts at 50 mA
price	$1.90 (minimum quantity 25)

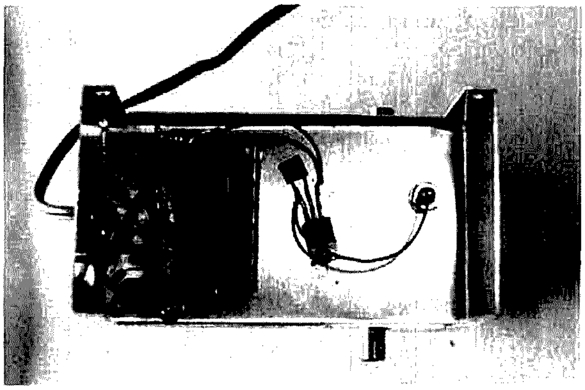


Photo B. Bottom view of the power supply components and wiring. The large tubular item in the middle is the 3300-μF capacitor.

tion of 1/2-watt dissipation. A 7815 regulator provides a convenient 15-volt source for the 10-volt drop.

My surplus thermistor-mount power meter goes down to almost −30 dBm. Notice the use of the word "almost" here; it indicates the difficulty in making measurements below −30 dBm because of thermal drift. Increasing the top end from 0 dBm to +10 dBm by adding this amplifier provides a 10-dB increase in total range, which represents significant improvement.

building the amplifier

The main objective of this project was to use fast, easy construction techniques with readily available parts. The components were soldered together on an unetched printed circuit board, with component leads cut as short as possible. Small 0.01-μF disc ceramic capacitors were used for coupling. **Photo A** shows the amplifier mounted in a small chassis box, which is mounted on a larger box housing a power supply. A circuit board is used as a ground plane and is fastened with small brackets. This type of construction avoids etched stripline circuit boards and chip components typical of microwave construction.[3] **Photo B** is an underside view of the power supply components and wiring. The large cylindrical item in the middle is the 3300-μF capacitor. Be careful when soldering the MMIC leads; they break easily.

Because this amplifier is a test accessory, it will be handled frequently, and you may find that screws and other parts loosen easily. Make sure that the connectors used for J1 and J2 are fastened securely; adding a drop of paint or glue to the mounting hardware will help prevent loosening. The feedthrough capacitor shown in **fig. 1** was a junkbox item which conveniently

Table 2. Measured test results.

frequency (MHz)	amplifier input power (dBm)
1	+1.0
3	−2.0
5	−2.6
10	−3.0
25	−3.0
50	−3.0
75	−3.0
100	−3.0
150	−2.9
200	−3.0
300	−2.8
400	−2.0
450	1.8

helps secure the small box to the larger one. It could be replaced with a disc ceramic.

Though a fairly well-stocked junkbox should include most parts, I've provided Radio Shack part numbers to simplify component acquisition (see **fig. 1**). To obtain the MMIC's, contact Mini-Circuits[2] and ask for the Mini-Circuits distributor nearest you. The distributor may or may not be able to fill a small order. Because there's no distributor nearby, I bought the DAK-1 Designer's Amplifier Kit of 30 assorted amplifiers for $49.99 (plus shipping) directly from Mini-Circuits; this price is slightly less than the quantity price of the individual ICs. The kit solves the problem of providing prototype samples for design engineers; perhaps some of the mail-order suppliers that cater to hobbyists will soon stock these new ICs.

measured results

The amplifier was connected between a signal generator and thermistor power meter using short RG-58 BNC cables to test gain and frequency response. The data shown in **table 2** was measured with the amplifier output power set to +10 dBm at each frequency.

The low frequency gain starts to roll off at 1 MHz because of the three 0.01-μF coupling capacitors. The small reduction in gain at 450 MHz may have been caused by the type of construction used and losses in the cables. I was delighted to find the amplifier stable and free from oscillation, with nearly constant gain over the frequency range of interest.

references

1. Joe Reisert, W1JR, "VHF/UHF World," *ham radio*, November 1986, page 91.
2. *RF/IF Signal Processing Guide 1986-87*, free catalog available from Mini-Circuits, P.O. Box 166, Brooklyn, New York 11235.
3. Jerry Hinshaw, N6JH, "Monolithic RF Amplifiers," *ham radio*, March 1986, page 23.

ham radio

VHF/UHF WORLD

Joe Reisert, W1JR

operating a VHF/UHF/microwave station

Just as in hf operation, good operating practices make VHF, UHF, and microwave operation a pleasure not only for you but for other Amateurs as well. These practices enhance your chances of experiencing some of the more exotic propagation modes and operating techniques. Since some Amateurs may be hesitant about entering the VHF territory, I'll devote this month's column to those practices, in hope that the information presented will ease their transition to the world above 10 meters and help increase the enjoyment for those already operating there.

frequency plans

Each Amateur band above 50 MHz covers a wider frequency spectrum than all the present hf bands combined! Furthermore, on VHF and above there are more types of transmission emissions than you'll find on the typical hf bands: CW, SSB, packet, a-m, RTTY, and slow-scan ATV. While the FCC has placed limits on types of emissions within each of these bands, the only real restrictions above 50 MHz are between 50.0 and 50.1 and 144.0 to 144.1 MHz, which are allocated exclusively for CW operation. Reference 1 lists all the Amateur frequency allocations above 50 MHz; reference 2 shows the microwave/millimeter-wave bands after the FCC update of March 1, 1986. Reference 3 lists the modes permitted on all Amateur bands.

After World War II, North American VHFers established gentlemen's agreements or frequency (usage) plans. This worked fine while the VHF bands weren't too populated, but started to break down in the 1970s as activity increased and the number of different emissions and repeaters in operation increased. Let's face it; weak-signal operation using CW or SSB is virtually impossible alongside an fm repeater radiating reasonable ERP (effective radiated power) from a mountaintop location!

In 1978, therefore, North American "band plans" were drawn up by the ARRL VHF/UHF Advisory Committee (VUAC) in accordance with the wishes of many users from various interest groups. I was the chairman of that committee when these plans were formulated. It wasn't an easy job to satisfy everyone. All inputs had to be integrated so that the overall band plan would be fair and equitable for the majority rather than the minority. At the same time, band plans had to allow some room for specialized communications such as EME and OSCAR. Finally, they had to have some flexibility for future operating trends. Believe me, there were some tense moments.

The first band plans that emerged were for the 2-meter, 135-cm (220-225 MHz), 70-cm (420-450 MHz), and 23-cm (then 1215-1300, now 1240-1300 MHz) bands. Still more or less as originally formulated, these band plans also established the primary "calling frequencies" (to be discussed shortly) that are now in use. Several years later band plans were formulated for the 6-meter and 33-cm (902-928 MHz) bands. These band plans are fairly comprehensive and also list recommended fm repeater pairs.[4]

Most important for weak-signal work is the recommended calling frequency on each band. When the Amateur population density is low, there's a need for a specific frequency to monitor for unexpected openings or to serve as a place for meeting new friends or greeting new arrivals on the band. Tuning or scanning the whole band isn't only time consuming; it can often result in missing stations who call a quick CQ, hear no takers, and move on.

Furthermore, with the lower power and narrower antenna beamwidth that are typical of the VHF and above frequencies, it's sometimes difficult to hear someone, even on the calling frequency. The modern antennas are sporting pretty clean radiation patterns, so don't forget to change your antenna beam heading occasionally. I'm sure that those who use the present calling frequencies will agree that this is a much more productive approach to locating other stations and band openings than the methods used in "the good old days."

Table 1. Recommended North American calling frequencies.

Band	Calling Frequency	Notes
6 m	50.110	DX
	50.200	National
2 m	144.100	CW
	144.200	SSB
135 cm	220.100	
70 cm	432.100	
33 cm	903.100	
23 cm	1296.100	
13 cm	2304.100	

Table 1 shows the recommended calling frequencies where applicable. A few suggestions are in order. Once contact is established on the calling frequency, it's common courtesy to QSY up or down at least 10 kHz in order not to QRM the calling frequency and to make it available for others to use. Always remember that many people may be monitoring or want to use the calling frequency whether the band is open or not, so don't tie it up needlessly!

However, if no one transmits, how do you know the band is open? *Never use the calling frequency as a tune-up frequency*. Find another frequency where you won't cause interference or blow the head off somebody who's monitoring the calling frequency. However, put out a call or CQ occasionally. You may be pleasantly surprised by a response.

HF versus VHF Dxing

If there's one major difference between operating on the hf and VHF bands, it's most easily summed up in the term "DX." Generally speaking, the communication distances on the VHF bands aren't those that many of us work on hf. As a result, VHFers have a different notion as to what constitutes DX. Working Europe, Africa, or Asia on 20 meters may be routine for an hf DXer; but for a VHFer, working over 250 miles on 2 meters may involve a greater degree of difficulty.

Consequently, VHF and UHFers need a different yardstick by which their accomplishments can be measured. For many years, while DXers on hf were busy contacting new DXCC countries, VHF and UHFers in North America were chasing new ARRL sections, states, or counties. Probably the most popular award was the WAS (Worked All States). However, without EME, a WAS award is virtually *impossible on 2 meters and above.* What do you do when you've worked all states that are available using all the normal propagation modes?

European VHFers have an advantage over North Americans: in Europe, an area slightly smaller than the size of the continental United States, there are more DXCC countries than there are states in the United States. However, Europeans still weren't satified and in the early 1960s devised a system called "QTH Locator" or "locator" for short.

Europe was essentially subdivided into latitude/longitude blocks, each 2 degrees in longitude by 1 degree in latitude. At mid-latitudes this locator system yielded a square measuring about 70 by 60 miles. Each square was given a two-letter designation between AA and ZZ. For more accuracy, each square was further subdivided to pinpoint the location down to a few miles. A typical European locator, then, had five characters such as FR30c for SK6AB or TH69c for UW6MA. Unfortunately, the European locator system couldn't be used elsewhere without ambiguities or duplication. Hence, when out-of-continent DX modes such as EME became popular, a different locator scheme was needed.

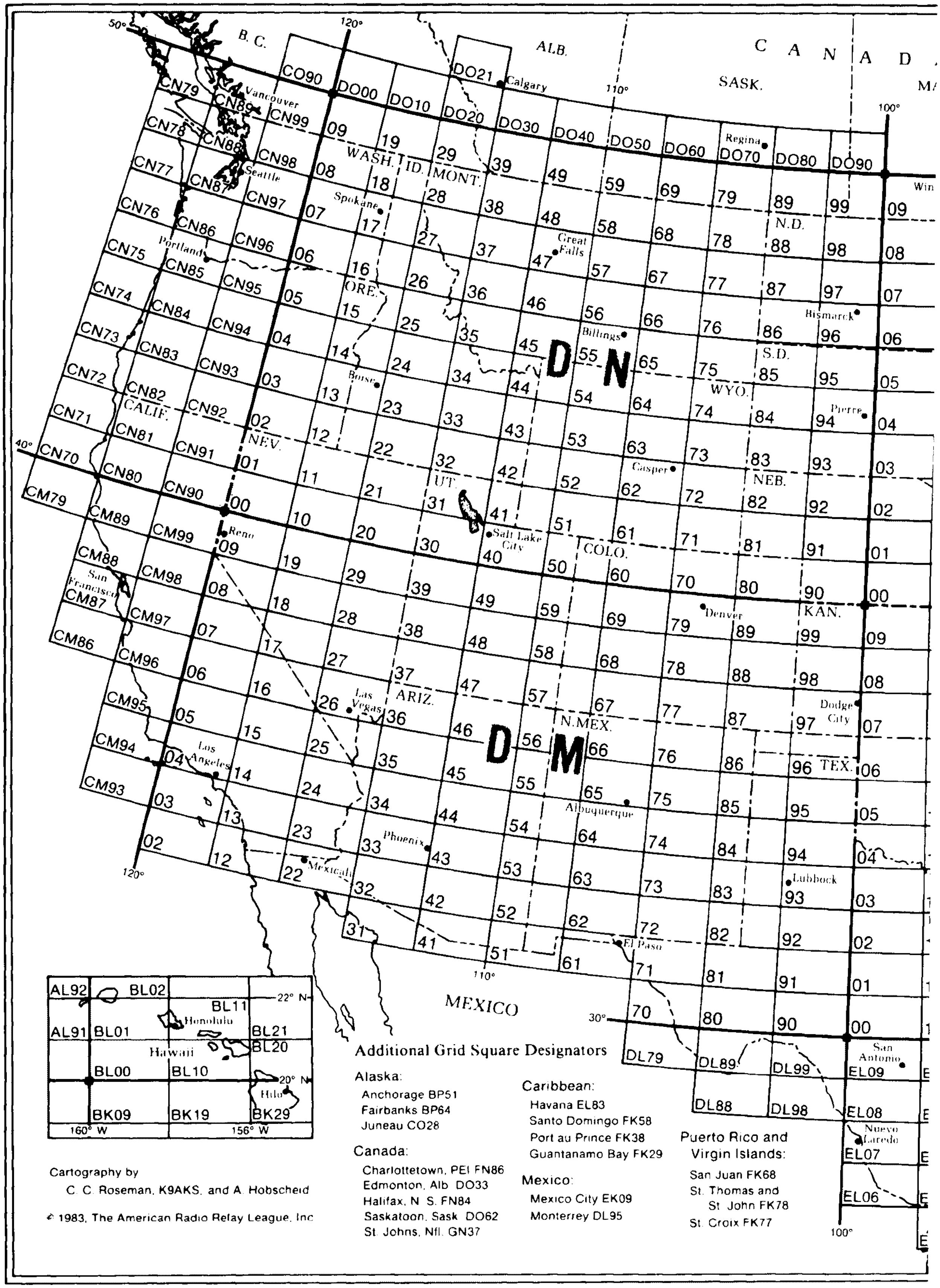
The search for a worldwide locator system was long and arduous. Several systems were proposed. The ARRL finally adopted the "Maidenhead" locator system, a scheme named after the town in England where a committee finally agreed upon a worldwide system without ambiguities.[5]

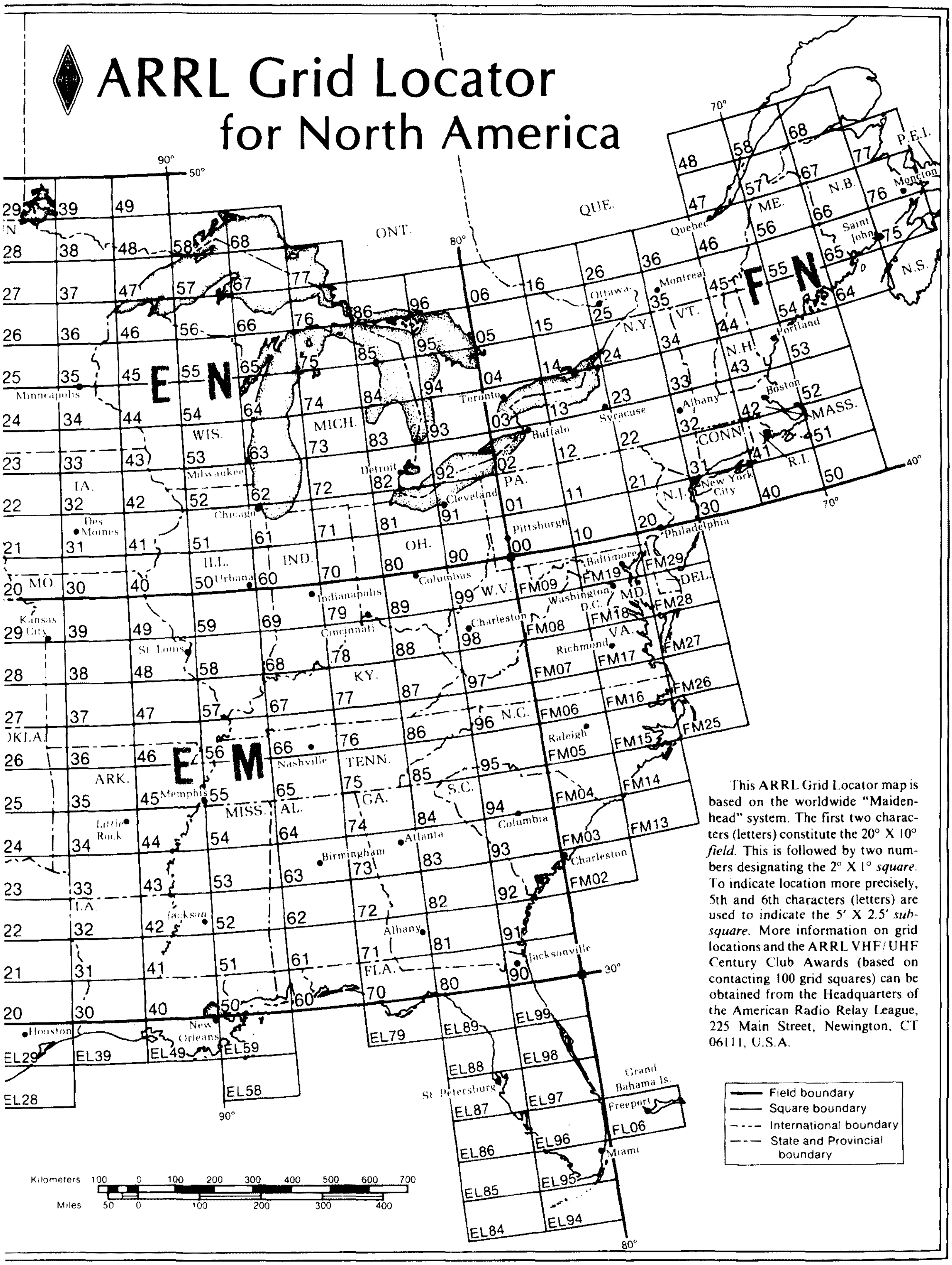
This locator system divides the Earth into 324 different "fields," each 20 degrees in longitude by 10 degrees in latitude. The system reference begins at the South Pole on the 180th parallel. Each field is given a two-letter designation between AA and RR. Each field is further subdivided into 100 different sections, numbered 00 thru 99, usually referred to in North American as "grid squares."

Figure 1 shows the ARRL grid square map covering the continental United States and lower Canada. If you live in this region and know your latitude and longitude (a must for all VHFers) you can quickly determine your four-character grid square using the map in **fig. 1.** Maps similar to this one are now widely available from various VHF equipment suppliers. If you don't know your grid square, just ask local VHFers. They'll be glad to assist.

However, note that a four-character locator has an accuracy of only approximately 50 to 75 miles. If greater accuracy — such as that offered by the European five-character scheme — is necessary, more information is required. In the Maidenhead system, two additional characters are used. Information on how to determine your six-character grid square may be found in tables listed in reference 5.

For example, my home is located at North latitude 42 degrees, 34 minutes, 58 seconds, and West longitude 71 degrees, 22 minutes, 35 seconds. Therefore the six-character grid square is FN42HN. When even greater accuracy is needed — on the microwave frequencies, for example — an eight-character system can be used by adding two more characters to pinpoint the exact location.


Additional Grid Square Designators
Alaska:
Anchorage BP51
Fairbanks BP64
Juneau CO28
Canada:
Charlottetown, PEI FN86
Edmonton, Alb DO33
Halifax, N. S. FN84
Saskatoon, Sask DO62
St. Johns, Nfl. GN37
Caribbean:
Havana EL83
Santo Domingo FK58
Port au Prince FK38
Guantanamo Bay FK29
Mexico:
Mexico City EK09
Monterrey DL95
Puerto Rico and Virgin Islands:
San Juan FK68
St. Thomas and St. John FK78
St. Croix FK77
Cartography by
C. C. Roseman, K9AKS, and A. Hobscheid
© 1983, The American Radio Relay League, Inc.
D N
D M
MEXICO
CANADA



This ARRL Grid Locator map is based on the worldwide "Maidenhead" system. The first two characters (letters) constitute the 20° X 10° *field*. This is followed by two numbers designating the 2° X 1° *square*. To indicate location more precisely, 5th and 6th characters (letters) are used to indicate the 5' X 2.5' *subsquare*. More information on grid locations and the ARRL VHF/UHF Century Club Awards (based on contacting 100 grid squares) can be obtained from the Headquarters of the American Radio Relay League, 225 Main Street, Newington, CT 06111, U.S.A.

fig. 1. This is a copy of the official ARRL VUCC grid locator map for North America. An 18 x 12-inch copy is available from the ARRL for $1.00.

Many home computer programs are now available for determining the six-character grid square for any point on Earth if the latitude and longitude are known. Conversely, there are now computer programs that will break out the longitude and latitude from a six-character grid square. Some of the programs will even determine the distance and bearing between two stations if the grid squares are known.

It's now common practice on 6 meters and above to exchange your four-digit locator or grid square when establishing initial contact with a new station. In fact, the use of grid squares has become so widespread in North America that one often has to ask the other station in which state they're located!

Table 2. Number of grid squares required for ARRL VUCC award.

Frequency	Grids Required	Endorsement increments
50 MHz	100	25
144 MHz	100	25
220 MHz	50	10
432 MHz	50	10
902 MHz	25	5
1296 MHz	25	5
2.3 GHz	10	5
3.4 GHz	5	5
5.7 GHz	5	5
10 GHz	5	5
24 GHz	5	5
47 GHz	5	5

VHF/UHF/microwave awards

As previously mentioned, the WAS award is still very popular in North America on the VHF frequencies. WAS has been obtained by several hundred Amateurs on 6 meters using ionospheric propagation. WAS has been attained on 2 meters by almost 100 Amateurs, but EME was needed because the distance necessary to work all states exceeds the normal propagation modes even for those located in the central part of the United States. Likewise, about ten WAS awards have been attained on 135 and 70 cm using all available normal propagation modes and EME.

The WAC (Worked All Continents) award is also available on VHF. Many 6-meter WACs have been issued, especially after the F2 propagation peaked a few years ago. WAC has also been accomplished by several dozen stations on 2 meters and 70 cm, but EME was required. Several stations are now waiting for the arrival of a South American Amateur on 23-cm EME to complete WAC on that band.

In 1981 the Central States VHF Society started an awards program using squares similar to those used in Europe. This scheme was eventually adopted by the ARRL; on January 1, 1983, they launched a new VHF awards program called the VUCC (VHF/UHF Century Club).[5] Based on the Maidenhead QTH locator system, it's the DXCC of the VHF world.

Each VHF band through 47 GHz now has its own separate VUCC award. Only confirmed contacts made on or after January 1, 1983 qualify. The minimum number of confirmed grid squares varies for each band, with the minimum established according to the degree of difficulty involved. Six and 2 meters require at least 100 grids, while 135 and 70 cm each require 50 grids. Stickers are available for specific levels above the minimum requirements.

Table 2 has been prepared to show the minimum number of grid squares required on each of the designated bands as well as the endorsement sticker requirements. Unlike the DXCC, for which several of us have already confirmed all 317 presently designated countries, the VUCC Award has 32,400 grid squares available for each of the bands shown in **table 2**. That should keep most VHFers busy for the forseeable future!

Think of the excitement you could have with a North or South Pole expedition, where you could put out 18 different squares just by moving your station a few feet for each square. Better yet, sit right over the Pole and put out all 18 polar squares simultaneously! What say, KC4AAA?

For those interested in the worldwide grid squares, Folke Rosvall, SM5AGM, has published a World Atlas showing all 32,400 grids superimposed on maps of the world along with principal cities and geographic boundaries.[6] I find this atlas indispensible for serious grid square work.

DX records

Ironically, *the most prestigious accomplishments on VHF have no awards!* The ultimate claim is to be one of the few who can document the best DX on a particular VHF frequency band. For many years this was done on a worldwide basis and hence the chance to claim a record was slim unless you lived near one of the strategic locations favored by one of the exotic propagation modes.

Therefore, in the July, 1985 column I introduced a North American-only DX record list.[1] This gave North American Amateurs a means of comparing their accomplishments more equitably with their peers. Furthermore, I added a twist by listing the records according to the suspected mode of propagation. This not only created many more mountains to climb, but also distributed the records according to the most favorable propagation in different regions of North America. Judging from all the calls and letters, this listing has generated substantial enthusiasm for new record challenges.

Occasionally I hear second-hand claims that individuals have or know of longer records, but are either unable or unwilling to produce the necessary material to document their case. Claims come cheap, so I disregard

Table 3. **North American VHF and above claimed DX records (revised March 18, 1987).**

Frequency	Record Holders	Date	Mode	Miles (km)
50 MHz	Note 3			
144 MHz				
Aurora	KA1ZE (FN31TU)-WB0DRL (EM18CT)	86-02-08	cw	1347 (2167)
Ducting	KH6GRU (BL01XH)-WA6JRA (DM13BT)	73-07-29	cw	2586 (4161)
EME	VE1UT (FN63XV)-VK5MC (QF02EJ)	84-04-07	cw	10,985 (17676)
Sporadic E	W4EQR (EM60IM)-W7HAH (DN28NB)	81-07-09	ssb	1891 (3043)
FAI	W5HUQ/4 (EM90GC)-W5UN (DM82WA)	83-07-25	cw	1229 (1977)
MS	K5UR (EM35WA)-KP4EKG (FK68VG)	85-12-13	ssb	1960 (3153)
TE	KP4EOR (FK78AJ)-LU5DJZ (GM04RO)	78-02-12	ssb	3933 (6328)
Tropo	K1RJH (FN31XI)-K5WXZ (EM12QW)	68-10-08	cw	1465 (2358)
220 MHz				
Aurora	W3IY/4 (FM19HA)-WB5LUA (EM13QC)	82-07-14	cw	1145 (1842)
Ducting	KH6UK (BL11AQ)-W6NLZ (DM03TS)	59-06-22	cw	2539 (4086)
EME	K1WHS (FM43MK)-KH6BFZ (BL11CJ)	83-11-17	cw	5058 (8139)
MS	K1WHS (FM43MK)-K0ALL (EN16NX)	85-08-12	ssb	1279 (2057)
TE	KP4EOR (FK78AJ)-LU7DJZ (GM04RO)	83-03-09	cw/ssb	3670 (5906)
Tropo	VE3EMS (EN86QJ)-WB5LUA (EM13QC)	82-09-28	ssb	1181 (1901)
432 MHz				
Aurora	W3IP (FM19PD)-WB5LUA (EM13QC)	86-02-08	cw	1182 (1901)
Ducting	KD6R (DM13NI)-KH6IAA/P (BK29GO)	80-07-28	cw	2550 (4103)
EME	K2UYH (FN20OF)-VK6ZT (QF78VB)	83-01-29	cw	11,567 (18612)
MS	W2AZL (FN20VI)-W0LER (EN35IE)	72-08-12	cw	1020 (1641)
Tropo	WB3CZG (FN21AX)-WA5VJB (EM12LQ)	86-11-29	ssb	1318 (2121)
903 MHz				
Tropo	W2PGC (FN02OR)-K3SIW/9 (EN52WA)	86-12-24	ssb	478 (769)
1296 MHz				
Ducting	KH6HME (BG29GO)-WB6NMT (DM12KU)	86-08-13	ssb	2528 (4068)
EME	K2UYH (FN20QG)-VK5MC (QF02EJ)	81-12-06	cw	10,562 (16995)
Tropo	WB3CZG (FN21AW)-KD5RO (EM13PA)	86-11-29	cw	1287 (2070)
2304 MHz				
EME	PA0SSB(JO11WI)-W6YFK (CM87WI)	81-04-05	cw	5492 (8837)
Tropo	KD5RO (EM13PA)-W8YIO (EN82BE)	86-11-29	cw	940 (1531)
3456 MHz				
Tropo	WA5TNY/5 (EM11AU)-WB5LUA/5 (EM24UQ)	86-10-19	cw	288 (464)
5760 MHz				
Tropo	K5PJR (EM26OP)-WA5CIW/5 (EM04HX)	86-11-22	cw/ssb	285 (459)
10.368 GHz				
Tropo	WA4GHK/4 (EL97SV)-WD4NGG (EM92PE)	84-08-07	FM	297 (478)
24.192 GHz				
LOS	WA3RMX/7 (CN93IQ)-WB7UNU/7 (CN95DH)	86-08-23	ssb	115.5 (186)
47.040 GHz				
LOS	WA3RMX/K7RUN (CN85OL)-WB7UNU/W7TYR/ W7ADV (CN85PL)	87-03-07	ssb	5.42 (8.72)
76-149 GHz				
	None reported			
474 THz				
LOS	K6MEP (DM04IO)-WA6EJO (DM04KT)	79-06-09	Laser	15 (24)

Notes:

1. The records are listed alphabetically by mode. Ducting is suspected when the path is mostly over water. No efforts are made to separate out ducting on overland paths, so they're grouped under tropo.
2. The information within the brackets is the grid square locator.
3. Six-meter records were omitted since the primary mode is often hard to distinguish. Also, long-path QSOs exceeding 12,433 miles (20,004 km) were reported during solar cycles 19 and 21.

them unless the proof can be obtained. All record claims must be two-way contacts on recognized Amateur bands using legal power.

Since the last North American claimed records list was published in January, 1987, there have been many changes; the pace quickens to increase records even if only by a few more miles.[7] **Table 3** shows the latest VHF and above record claims. I've also added a further refinement by listing (to the best of the information received) the six-character grid square location on each end of the record.

Again, I offer a challenge. If you think you've bettered one of the records shown, send me a note with some pertinent information on the claim and I'll return a record claim sheet for verification. Fair enough?

QSLing

Yes, QSLs are required for most awards, even on the VHF frequencies. QSLs can be revered; unfortunately, they're worthless if improperly documented. Show pride – not only in your QSL, but in paying attention to the details on the QSL. Always include the following minimum information on your QSL cards: your call sign, the other station's call, your QTH and grid square, the date and time of your QSO, plus your frequency and emission type. The following additional information is also recommended: the propagation mode, a signal report (try to note this in your log even though it may not be used at the time – during contests, for example); your six-character grid square or exact latitude and longitude, a description of your equipment, some comment on the weather, and any other pertinent information. The latter information could immensely assist others who are trying to evaluate propagation or station performance.

Always use UTC time and date. There's a special problem on 6 meters in North America, since over half the sporadic E openings occur in the early evenings between 2200 and 0300 UTC, during which the date changes! There's nothing more frustrating than trying to verify a QSO in your log when there are 50 to 100 QSOs (or more during contests), all on the same date, and you get a QSL from another time zone. *UTC is universal.* If UTC is a problem to figure, buy an inexpensive clock just for logging and set it on UTC, as given by radio station WWV. Note the UTC date; it's just as important as the UTC time!

Finally, be careful when dating QSLs so there's no ambiguity about the month and day. Many years ago dates were customarily given as month-day-year (for example, 6/12/87); slowly the trend has changed to day-month-year (that is, 16/6/87). Now there seems to be a feeling internationally that this is confusing.

The newest date system suggested by the IARU (and by many governments) is to indicate dates by stating the most important parameter, namely the year, first. The month and day follow (for example, 87/6/16). I now use this format in my log and had my latest QSLs printed this way. There's no longer any confusion about which part of the date is being numbered, especially when exchanging QSLs internationally. Don't you agree?

I often receive QSLs sent as postcards. Quite frankly, most of these arrive looking as if they'd been through a meat grinder and are often illegible, with postage stamps obscuring important information – such as the date! I strongly recommend that you show a little pride and always send QSLs in a protective envelope even though the cost will be higher.

Please answer all QSLs received on the VHF bands. What may seem like an easy contact to you may have been like climbing a mountain for the other person. QSL as soon as possible after a contact; the longer you wait, the less chance of a return. We live in a mobile society. People move, lose interest, and often postpone answering QSLs, especially if a large batch arrives.

Finally, don't forget the SASE. QSLing is no longer an inexpensive proposition. If you want a reasonable guarantee of a QSL in return, including an SASE is the least you can do. One exception is when both parties want a card and mutually agree ahead of time to dispense with the SASEs.

what constitutes a QSO?

Does this sound like a stupid question? I don't think so – not when it's applied to VHF and above. With the arrival of new operating techniques and the use of more exotic propagation mechanisms, many QSOs are no longer straightforward and may require more than a few seconds to complete. It may be more a matter of minutes or even hours.

Let me be more specific. I believe that the minimum requirements for a valid contact are a two-way exchange of both call signs, some type of information, and a confirmation that all this information was received.

The call sign exchange should be obvious. If both call signs aren't heard by both stations, how can you be sure who you're communicating with – especially if signals are weak? I totally deplore the often single-call contest type of contacts, presently so popular on hf and beginning to appear on VHF.

When you call a station for the first time, send his or her call sign followed by your call sign. If several stations call simultaneously (such as in reply to a CQ), there may be confusion. It's often easier and quicker to sign both calls twice, once at the beginning and once at the end of the first information exchange, rather than repeat them in QRM if two stations reply.

The exchange of some specific information may require some amplification. On hf and often on VHF, this is usually a signal report such as RS(T). Nowadays, it's popular on VHF and above to just exchange grid squares. There's nothing wrong with this. On EME and meteor scatter, the exchange is usually a letter or abbreviated report such as "S2" on meteor scatter. Again, there's nothing wrong with this as long as it's mutually understood by the two stations having the contact.

The exchange of information shouldn't be sent until the call signs are

confirmed. After the information exchange, the most crucial part of the contact takes place; this is the confirmation that all the necessary information has been received. Frequently this is accomplished by an "R" on CW or "roger" on SSB.

Most operators agree that the roger should never be sent until both call signs and all the information exchange is completed. Furthermore, most operators agree that the contact is complete when at least one of the stations hears a roger and then responds with same. Some purists may want to hear rogers both ways, but that can lead into the roger-of-the-roger syndrome.

If there's any doubt about the confirmation required, try to get a definition of what the other station requires ahead of time. One scheme I use to break the routine is to send 73, but I never send it unless I'm sure that the other station has received my roger. When you hear my 73, you know that I've received all the necessary ingredients for a completed QSO.

transmission modes

Nowadays most weak-signal communications use SSB on the VHF/UHF frequencies because it has a much faster information exchange. This is especially true on meteor scatter, where some bursts are measured in seconds. CW is usually reserved for long-haul, weak-signal paths, EME, and aurora, where signals are more difficult to copy, especially when there's severe distortion or doppler shift.

More specific information is required to operate meteor scatter and EME because they each have a special reporting format. On meteor scatter contacts, stations in North America usually transmit and receive in 15-second increments. Generally speaking, the station furthest west or south transmits the first and third 15 seconds of each minute and the station furthest east or north transmits the second and fourth 15 seconds. More specifics are discussed in reference 8.

EME operation is another matter because it differs on each band. Transmission periods are typically 2 or 2-1/2 minutes and special reporting sequences are used. 70-cm reporting and scheduling are discussed in reference 9. Time and space won't allow a lengthy dissertation at this time, so these matters will have to be covered at a later date.

Table 4. Suggested activity nights and contest activity hours (see text).

Band	Activity Night	Activity hours during contests
6 meters	Sunday	6 AM/PM
2 meters	Monday	7 AM/PM and 1 PM
135 cm	Tuesday	8 AM/PM and 2 PM
70 cm	Wednesday	9 AM/PM and 3 PM
23 cm	Thursday	10 AM/PM and 4 PM
33 cm	Friday	11 AM/PM and 5 PM

when and where to operate

So far I've discussed band plans, grid squares, awards, QSLing, and what constitutes a two-way contact. By now you're probably asking, "Where do I go to find all those stations to contact?" One answer is to tune into the various calling frequencies and scan 10 to 25 kHz on either side of them. If nothing is heard, try a CQ on one of the calling frequencies.

If you still don't hear anyone, don't be alarmed. Your rig is probably working, but there just isn't any activity at the time. "So when is the activity?" you ask. The answer is sometimes a function of your location. You may have to be patient at first or ask a local Amateur when it all takes place.

• **Activity nights**. Sometimes activity can be sparse, especially on the higher VHF and UHF bands. Many of the "dyed-in-the-wool" VHF/UHFers operate on more than one band. But you can't be everywhere all the time — thus the concept of "activity nights."

Basically the scheme goes like this. Each night of the week is designated for a different major VHF/UHF band. This way you can pool your resources and cover all bands equally. This concentration has been proven to be very effective and easy to remember. Sunday night is 6-meter night, Monday is 2-meter night, and so forth; **table 4** shows the whole scheme. Local areas choose the time, but it's typically between 8 and 10 PM local time.

• **Contests** usually provide plenty of VHF/UHF activity. The major North American contests are listed at the end of this column. Again, the operation can get out of sync; that important multiplier may be on a particular band when you're busy elsewhere. Therefore, activity hours are recommended during contests. Here in the Northeast, 7 AM and 7 PM are 2-meter hours, 8 AM and 8 PM are 135-cm hours, and so forth. These times are also shown in **table 4**.

• **Nets** are another source of activity. SMIRK (Six Meter International Radio Klub) and SWOT (Sidewinders On Two) have local nets. Some clubs do the same. AMSAT/OSCAR has hf band nets where VHF/UHFers can be found. This a good way to seek out activity. Six-meter operators can often be found on 28.885 MHz when band openings are expected or for cross-band (6 to 10 meters) operation.

Many special-interest VHF/UHF nets convene on hf so that wider area coverage can be conducted. The Central States VHF Society has a net on 3818 kHz on Sunday evening. I believe it's at 10 PM Central Time. Members and nonmembers can often be found on this frequency in the evenings, especially during meteor showers. The 70-cm EME net meets on 14.345 MHz every Saturday and Sunday at 1600 UTC, followed by the 2-meter EME net at approximately 1700 UTC.

• **VHF/UHF and microwave conferences**, many held annually, are usually listed at the end of each month's column (if I get the informa-

tion in time). Conferences are a great way to meet other VHF/UHFers and to get tips on operating a station, improving your equipment, schedules, and activity.

Another nice thing about VHF/UHF/microwave conferences is that they often have noise figure measurement gear so you can tweak your preamplifiers and know how good (or bad) they really are. Often antenna measurement is available. This is a good way to see how your favorite antenna stacks up against the competition.

• **Publications** offer another great source of activity. All the major Amateur journals in the United States now have special VHF columns. In addition, there are literally dozens of club newsletters, *magazines*, and specialized publications that are good for locating activity and finding out how to improve your gear. Many of these were discussed in my March, 1985 column, so they won't be repeated here.[10]

At the risk of leaving someone out, I've prepared table 5, which lists some of the major North American VHF/UHF newsletters not connected directly with any club or organization. If there's interest in updating the information in reference 10 or listing the various club newsletters, let me know. Just send me the information on your publication; perhaps we can publish it at a later date.

Table 5. Several major North American newsletters that are not directly associated with a club or organization.

VHF/UHF and Above Information Exchange, c/o Rusty Landes, KA0HPK, P.O. Box 270, West Terre Haute, Indiana 47885. Issued monthly. One-year subscription: $15.00.

KC0W's *UHF-Plus Update*, 3090 Point Pleasant Road, Hebron, Kentucky 41048. Issued monthly. One-year subscription: $5.00.

220 Notes, c/o Walt Altus, WD9GCR, 215 Villa Road, Streamwood, Illinois 60103. Issued quarterly. One-year subscription: $5.00.

2-Meter EME Bulletin, c/o Gene Shea, KB7Q, 417 Staudaher Street, Bozeman, Montana 59715. Issued monthly. One-year subscription: $15.00.

join a club or society

If you really want to get involved and meet people, join one of the many VHF/UHF or microwave clubs or societies. They range from small groups of several individuals sharing a newsletter to larger ones with hundreds of members who sponsor conferences. This is an excellent way to get tips on operating.

Again, it would be difficult to list all the clubs and societies. My list is incomplete at this time. If you're not already sending me your newsletter, please send a sample copy and information on joining. Perhaps we can run lists of these in a future column.

conveniences

All your operation can go for naught if some conveniences aren't provided. Try to make your operating position as comfortable as possible. Have a separate light over the operating position so that your log book can easily be seen. It will not only be less tiring, but safer if you have to make any gear changes.

Have keyers and microphones readily accessible on the operating table. If any antennas have to be switched, provide a switch, preferably with easy access from the operating position. Don't take any shortcuts on an antenna relay. A poor isolation or unreliable relay can cause instant equipment burnout.

Finally, if possible, have a secondary frequency standard.[11] Not only will it tell you what frequency you're on, but it will provide a weak signal source to indicate whether your gear is grossly inoperative.

summary

This month's column, devoted to operating a VHF/UHF/microwave station, was further dedicated to newcomers to ease and speed their transition to the VHF and above frequencies. Various tips for improving your chances of success were also offered.

Remember to let me know about any VHF/UHF/microwave clubs, societies, newsletters, and conferences. I'll be glad to share the information I receive in a future column.

new records

Reference 7 indicated that the best reported DX on 48 GHz in North America was a puny 0.3 miles. That's all history now, as you'll note in **table 3**. That record was broken on March 7, 1987 when WB7UNU, W7TYR, and W7ADV in Portland, Oregon (CN85PL), had a two-way SSB contact on 47.040 GHz with WA3RMX and K7RUN in Beaverton, Oregon (CN85OL), over a distance of 5.42 miles!

Not only is this a new North American record, but it probably represents the highest frequency at which narrowband SSB communications has ever taken place. The power was only 44 microwatts into a 9.5-inch diameter dish on one end of the path! The power on the other end of the path was 3.5 milliwatts (QRO!) into a 28.5-inch dish. Judging from the signal strength and low power, this same group has immediate plans to break their own record. Congratulations all around and good luck on your next record attempt.

Important VHF/UHF Events

July 1	*± 1 month. Look for European 6-meter opening.*
July 11	*EME perigee*
July 18-19	*CQ Magazine VHF WPX Contest*
July 20	*± 2 weeks. Look for 2-meter sporadic E propagation.*
July 23-26	*Central States VHF Conference, Arlington, Texas (contact KD5RO)*
July 29	*Predicted peak of the Delta Aquarids meteor shower at 1500 UTC*
Aug. 1-2	*ARRL UHF Contest*
Aug. 1-3	*SWOT (Sidewinders On Two) open QSO party (contact K5IS)*
Aug. 8	*EME perigee*
Aug. 12	*Predicted peak of the Perseids meteor shower at 1300 UTC*

references

1. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Propagation Update," *ham radio*, July, 1985, page 86.
2. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-Wave Propagation — Part I," *ham radio*, July, 1986, page 82.

3. Richard K. Palm, K1CE, editor, *The FCC Rule Book*, an ARRL publication, available from Ham Radio's Bookstore for $4.00 plus $3.50 shipping and handling.
4. Bart J. Jahnke, KB9NM, editor, *The ARRL Repeater Directory*, 1986-1987 edition, an ARRL publication. 1987-1988 edition available from Ham Radio's Bookstore for $4.00 plus $3.50 shipping and handling.
5. John F. Lindholm, W1XX, "VHF/UHF Century Club Awards," *QST*, January, 1983, page 49.
6. Folke Rosvall, *The Radio Amateur's World Atlas*, available from Ham Radio's Bookstore for $4.00 plus $2.00 shipping and handling.
7. Joe Reisert, W1JR, "VHF/UHF World: Microwave and Millimeter-Wave Update," *ham radio*, January, 1987, page 63.
8. Joe Reisert, W1JR, "VHF/UHF World: Improving Meteor Scatter Communications," *ham radio*, June, 1984, page 82.
9. Joe Reisert, W1JR, "Requirements and Recommendations for 70-cm EME," *ham radio*, June, 1982, page 12.
10. Joe Reisert, W1JR, "VHF/UHF World: Keeping VHF/UHFers Up to Date," *ham radio*, March, 1985, page 126.
11. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Frequency Calibrator," *ham radio*, October, 1984, page 55.

ham radio

important news about MININEC 3

In W1JR's column in the May, 1987 issue (see page 101), it was erroneously stated that copies of MININEC 3 could be obtained from the United States Naval Ocean Systems Center (NAVOCEANSYSCEN).

According to NAVOCEANSYSCEN, engineering software such as MININEC is developed by NAVOCEANSYSCEN for use by the United States Navy and other Department of Defense (DOD) agencies. NAVOCEANSYSCEN software is made available to the DOD and DOD contractors upon written request as part of the technology transfer goals of NAVOCEANSYSCEN.

The documentation for MININEC 3, NOSC Technical Document No. 938, is available to the general public at a nominal fee from the National Technical Information Service (NTIS). Copies of MININEC 3 on diskette will be available from the Federal Software Exchange Center, a service of NTIS. To request copies, please contact NTIS at 5285 Port Royal Road, Springfield, Virginia 22161 (703 487-4650).

Please note that foreign requests must be handled through appropriate diplomatic channels. — Ed.

improved gain distribution
for the Yaesu FT-726R

Wake up your receiver with this simple mod

Yaesu's **FT-726R** is a very popular and well-made radio, offering a lot of flexibility in one small package. But some owners feel that for the 726R to really "come alive" on 2 meters, it's necessary to add an external GaAsFET preamp.

After owning a 726R for several days, I too felt that performance on the 6- and 2-meter bands could be improved. My observations lead me to believe that any shortcomings were not the result of insufficient front-end gain or a high noise figure, but were due instead to an apparent lack of i-f gain in the VHF modules. While the receiver's MDS seemed to be a cut above most other stock transceivers, signals that are too weak to activate the AGC threshold level require the operator to continually ride the a-f gain control for adequate recovered audio. The actual spread between the receiver MDS point and start of AGC action is considerable, resulting in an appreciable weak-signal "dead-zone."

It's interesting to note that the UHF 430- and 440-MHz modules don't suffer from this problem. This is because of the additional overall gain produced by the 70-MHz i-f stages unique to these modules. While switching bands, note how the receiver background noise increases when the UHF module is activated.

does a preamp really help?

I live in Connecticut's "Kilowatt Valley." During contests a multitude of high-power VHF stations surround my QTH and put the best of receivers to the test. The Yaesu 726R uses a single-ended dual-gate FET mixer preceded by a dual-gate FET high-gain amplifier — hardly a "crunch-proof" combination! Whatever benefits offered by a 20-dB GaAsFET preamp would be significantly outweighed by greatly diminished receiver dynamic range.

where gain will do some good

Two cascaded monolithic i-f "roofing" — or IMD — filters follow the first mixer, providing the first real degree of receiver selectivity. These filters protect the subsequent stages from strong signals falling outside the filter passband. While the filter bandwidth isn't adequate for closely spaced SSB/CW signals, the real limiting factor with the 726R lies in its VCO phase noise-produced reciprocal mixing products.

A common-gate JFET stage provides all of the i-f gain in both the 6- and 2-meter modules. Adding another 10 to 15 dB of i-f gain will solve most of the receiver sensitivity problems.

the circuit

Figures 1 and **2**, respectively, show the original and modified circuits. An additional FET stage was added to produce the needed gain. While there were many ways to do this, my method involves only minimal disruption of the existing circuitry; the radio may be returned to its original condition without difficulty. *The component values are critical. I deliberately used interstage mismatching and resistive loading to assure predictable gain and a stable circuit.*

The added components are mounted "cordwood" fashion on the rf unit pc boards for the 2- and 6-meter modules. The modification is neither lengthy nor involved, but some manual dexterity and soldering skills are needed. Don't perform these modifications if you're not comfortable tearing into your radio. Since the rf boards for both VHF modules are nearly identical, and many of the Yaesu part numbers are the same, I'll give the 6-meter information in parentheses only when the part numbers differ.

Only six parts are needed per module; total cost should be about \$10 for both modules. Use 1/8-watt resistors if available, and use the smallest size capacitors you can find. Extremely short, direct connections must be used for stability — there's a fair amount of in-line gain at 10.7 MHz with the additional i-f stage. I suggest pre-tinning the component leads before mounting. Be sure to use a grounded iron.

step-by-step procedure

Carefully remove the modules from the radio. Re-

By Peter J. Bertini, K1ZJH, 20 Patsun Road, Somers, Connecticut 06071

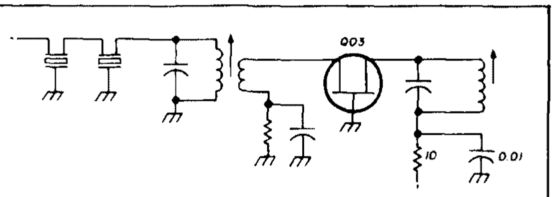


fig. 1. Original circuit.

gate lead and ground; use the coil shield for TO9 (TO8 in the 6-meter) as the ground point. Using short leads, tack-solder the 24-pF capacitor between the gate lead of the 2N5486 at the 1.8-k resistor junction and to the junction of the Q03 drain lead and the 6.8-μH choke. This completes the modification to the radio.

Check your work again for errors, making sure that none of the JFET leads have twisted and shorted together.

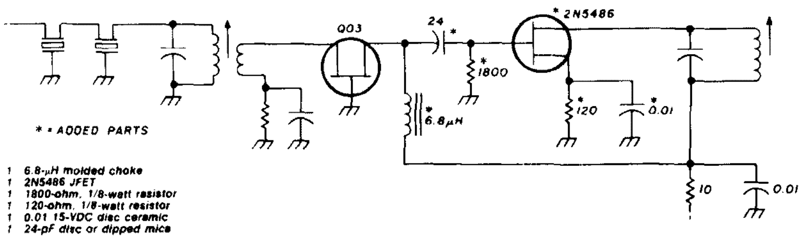


fig. 2. Modified circuit.

move the top cover shield for the rf board, which is held in place with four screws. Carefully lift the board upwards and locate the drain lead for Q03, the 2SK125 i-f amp. Unsolder this lead carefully and lift it from the pc run. Re-dress the lead as shown in **fig. 3A**. Because there's a small possibility that the lead may break off at the device case, you may wish to have a few RCA SK replacements on hand.

Preshape the 6.8-μH choke leads as shown in **fig. 3B**. Locate the resistor lead on the 10-ohm resistor (R19) nearest capacitor C34 (C32 for 6 meters) and carefully tin the lead. Slide the L-shaped hook lead of the 6.8-μH choke under the resistor lead and solder. Carefully shape and tack-solder the free drain lead from Q03 to the free choke lead — another lead will be added here later.

Preshape the 2N5486 leads as shown in **fig. 3C**. Arrange the source and gate leads so they face towards the J02 pin connections and insert the drain lead into the hole previously used by Q03's drain lead. Solder the lead to the PCB run and trim. Check your work carefully. If everything appears to be correct, reinstall the rf board for the 6-meter module only.

A 120-ohm resistor and 0.01 μF capacitor are installed between the 2N5486 source lead and ground. On the 2-meter module there are holes for an unused i-f transformer that will provide a good short ground path to the pc ground foil. For the 6-meter module the coil shield for i-f transformer TO8 is used; be careful not to overheat the coil assembly. The 2-meter rf board may be reinstalled at this point.

Next, a 1.8-k resistor is installed between the 2N5486

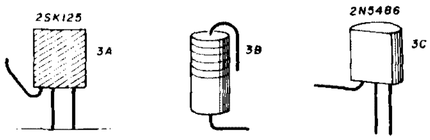


fig. 3. Preshape leads as shown.

alignment

Connect the module to the radio and let it sit atop the other modules so that the i-f transformers can be aligned. Inject a signal into the receiver that's strong enough to produce S-meter deflection; keep the level under S9 so that small signal variations will be more readily apparent. Carefully repeak coils TO8 and TO9 (coils TO7, TO8, and TO9 for the 6-meter module) for maximum meter deflection; repeat the procedure until no further improvement is noted. There should be no signs of regeneration or oscillation. When alignment is completed, remove power from the radio and reinstall the rf cover shield and the module in the radio.

increased performance

With no antennas connected, the receiver background noise is at the same level regardless of the band selected. Signals are about 10 to 15 dB stronger than before the modification. Weak signals that were difficult to copy are now easy to copy without an external preamp.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

that golden day

Some readers may remember my April column, wherein I mentioned the "black hole" in Amateur Radio, an area of western China between India and the USSR. Known as Xinjiang Province — and void of Radio Amateur activity — it measures some 600 miles in diameter.

But now BY0AA was rumored to be active in Ulumqui! One afternoon around 0100Z, I was tuning around 14,127 kHz when I heard a weak, watery signal working a UA9 station. Could this be . . . ? I closed my eyes — all good DXers know you can hear a weak signal better with your eyes closed — YES! The signal signed BY0AA. This was my chance. No one else was calling . . . the frequency was clear. To avoid alerting the competition, I gave a quick one-by-two: BY0AA DE W6SAI W6SAI K.

The room filled with a golden light. I heard the BY come back to me, but my mind slipped back to the early days of DX when I was a high school lad. The goal of active DXers then was to achieve the near-impossible: WAC (Worked All Continents) on phone!

It wasn't hard from the west coast, because a few Asians were on phone, but their signals never seemed to filter through to the New York area. True, a few DX giants such as W2AZ, W2HUQ, W2IXY, and W4DLH had done the impossible, but never a greenhorn kid running 120 watts into a dipole.

And then on that long-ago golden day, when the big DXers must have been asleep, I worked VU2CQ in Bombay, India on phone. It was truly a shattering experience and one not repeated until I had the thrill of working a station in the elusive "black hole" — Xinjiang province, formerly known as Chinese Turkestan!

Other DXers share the same exciting experience. The *1986 Top Band Annual News Digest* edited by Ivan Payne, VE3INQ, is a revelation. Armed with a good antenna, sufficient power, stamina, and an urge to excel, a group of 160-meter DXers are turning the top band into a replica of 20 meters! According to Ivan's DX log, W8LRL has 203 countries on 160, followed by N4PN and VE1ZZ with 184 and 189, respectively. And G3SZA and PA0HIP both have 39 zones on 160 meters! Now that's real DX!

a wideband 80-meter antenna

The wideband 80-meter antenna is still an elusive concept. The best way of doing the job is to make a "fat" dipole. Some of these designs have been shown in earlier columns. I recently received a note from Frank Geisler, W7IS, who had built various "fat" cage antennas for 80-meter operation. They seemed to work after a fashion, but they were large and unwieldly. They were easy to tangle up during erection and had heavy wind loading.

Searching for a better solution, Frank came up with the antenna shown in **fig. 1**. Very simple, it consists of five dipoles connected in parallel. The complete antenna is only 114 feet long. The short dipoles have a 2-foot separation so that overall spread of the wires is 10 feet. This interesting antenna is easy to get up in the air because only one wire is erected at a time. The top wire is pulled up first, then the other wires are added, one at a time, from top to bottom. Frank used No. 18 wire and cut all the dipoles to the same length. The operating bandwidth is sufficient to cover the range of 3.5 to 4.0 MHz with an SWR of less than 2:1.

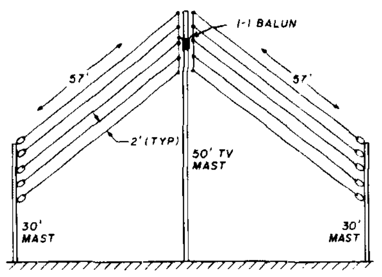


fig. 1. The 80-meter wideband dipole at W7IS.

No spreaders are necessary in this simple antenna. The wires have never tangled — not even in 60-mph winds. The wires attach separately to the center mast and are connected together with a short length of wire. A 1:1 balun is used to match a coax line.

Next, Frank wants to try reducing the number of wires to three, separated by 4 feet. It will be interesting to see if he can maintain operating bandwidth with fewer wires.

a 160-meter discone antenna

W7IS is a stalwart experimenter. He had always wanted to try a discone antenna for 160 meters to achieve vertical polarization with good operating bandwidth (see **fig. 2**). The top disc was assembled from wire and was 90 feet in diameter! The disc was preassembled on the ground and hauled

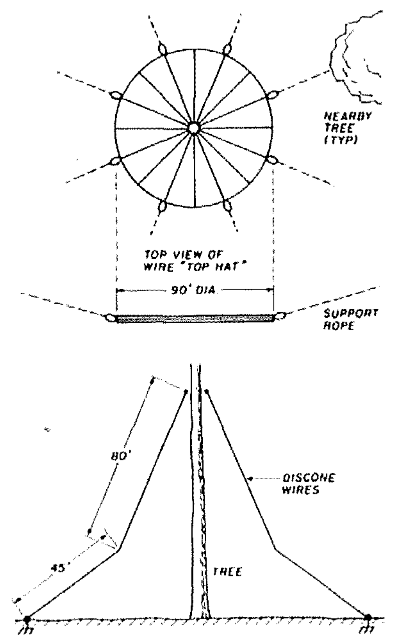


fig. 2. Side view of W7IS 160-meter discone antenna.

into position at the 80-foot level! He used nylon ropes to steady the assembly. The ropes ran to seven nearby trees. Pulleys and weights on each of the ropes allowed the top disc to flex in the wind.

The center support tree was 80 feet high and the discone wires were 130 feet long. The cone wires dropped down to the 10-foot level and then were run along the ground at this level for 45 feet. The natural resonance of the antenna turned out to be 2.1 MHz, so an antenna tuner was used to reach 1.8 MHz.

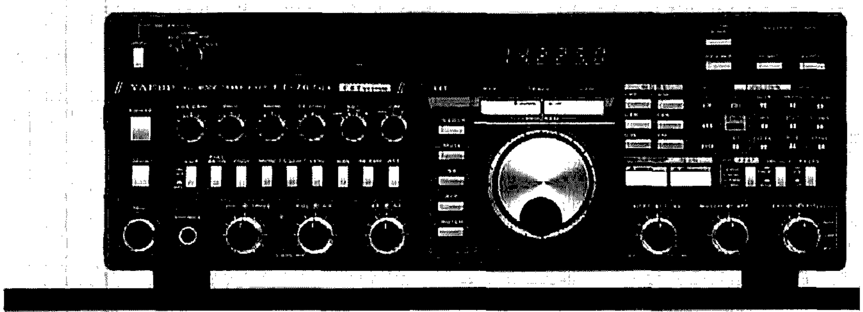
The last step was to ground the end of each discone wire with an 8-foot rod. All ground rods were tied together. This lowered the resonant frequency of the antenna to 1.8 MHz and dropped the SWR to less than 3:1 over the range of 1.8 to 7 MHz.

Frank states this was a major construction project that required large amounts of No. 12 wire. The antenna has been up for three years and is still in use. He says the antenna is good for DX and illustrates how much better vertical, rather than horizontal, polarization is on 160 meters.

For a simple 160-meter DX antenna, Frank says it's very hard to beat a simple dipole about 80 feet high. The discone is a better antenna, but it's difficult to construct, takes up a lot of wire, and requires plenty of real estate!

the 160-meter beam at PY1RO

The robust signal of Rolf, PY1RO, is well known to all 160-meter DX operators. He's tried various antennas and says that the array shown in **fig. 3** is one of the best. Suspended from a 230-foot tower, the array consists of six half-wave (quad style) loops, equally spaced around the tower. They use two half-loops as a director, two more



half-loops as reflectors, and the remaining loops as a "fat" radiator. The loops are electrically switched in six different directions. Polarization is vertical and a front-to-back ratio of better than 10 dB is noted. Front-to-side ratio is about 15 dB.

The switch box is located at the 16-foot level. Because each of the loops is self-resonant at 1925 kHz, they act as "natural" directors at the low frequency end of the band. The relays add sufficient length to the loops to make them resonant at 1740 kHz to act as reflectors.

Rolf notes that the high tower is a natural attraction for lightning. During a recent storm, he had two direct hits on the tower in the space of two hours. The installation is protected by a lightning arrestor (charge dissipator, or lightning rod) at the top and by six grounds at the bottom. Unfortunately, the coax from tower to station was left

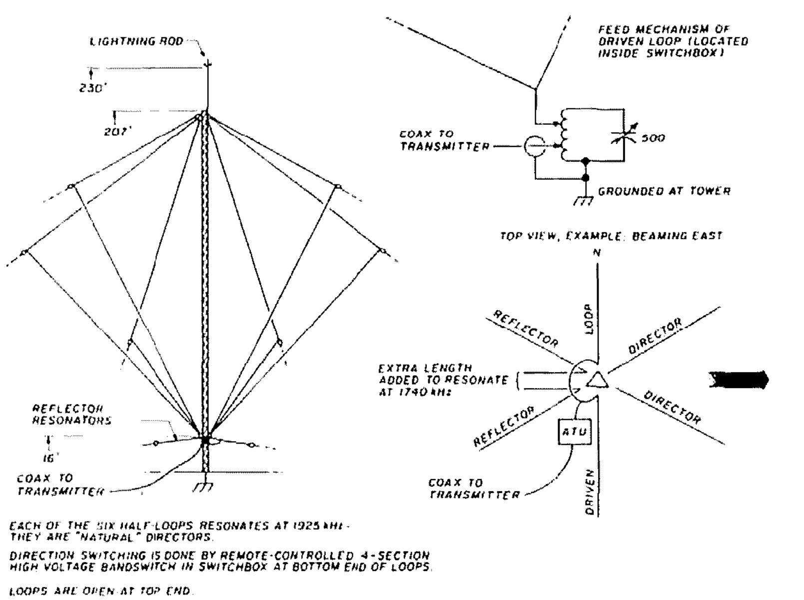


fig. 3. "Rotary" beam for 160 meters at PY1RO (courtesy VE3INQ).

connected during the storm. His station suffered extensive damage, including charred connectors, outlets, and wire all the way back to the circuit breaker box! Now, *all* wires to the tower are disconnected during a storm!

a one-chip, dual-conversion fm receiver!

Interested in an ultra-compact VHF fm receiver? Motorola has just announced the MC3362 bipolar analog IC, which comprises a single-chip receiver from antenna input to audio amplifier output. Useful from 50 to 150 MHz, the device provides excellent sensitivity and good image rejection in narrowband voice and data link applications.

The MC3362 was featured at the recent RF Expo East as a single-chip receiver operating in the 2-meter band (144.585 MHz) and drew crowds of interested Amateurs and engineers! For more information on this formidable device, contact Motorola, Inc., Bipolar Analog IC Division, Tempe, Arizona 85200.

new EME directories

A new supply of the popular "144 MHz EME Directory" has been printed. This lists many of the moonbounce stations and operators, giving the name, call, address, phone number (where applicable), and equipment. To obtain your copy, send five first-class stamps (or five IRCs) to me at EIMAC, 301 Industrial Way, San Carlos, California 94070.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

battery problems: part 1

As its title states, this column covers the practical aspects of Amateur Radio. Yet because much of my electronic servicing career has involved working with non-Amateur applications, it would seem to make sense to share some of the results of that experience with you here, since the principles addressed apply to Amateur Radio as well.

As I've mentioned before, I spent several years working in biomedical electronics at a large university medical center, where batteries were used for many different reasons. Some equipment was battery-powered for reasons of portability. A defibrillator, for example, might be needed anytime, anywhere . . . heart attacks don't always happen when patients are conveniently near electrical outlets or fixed-location machines. Although most of our defibrillators were ac- or dual-powered, we also had a number of purely battery-powered models.

We had battery-powered monitors used to keep track of ECG and blood pressure as patients were transferred between units — for example, from the Emergency Room to the Intensive Care Unit. Small VHF/UHF fm ECG telemetry transmitters kept track of ambulatory patients, and still other devices relied on battery power for reasons of patient safety. A cardiac output computer, for example, makes measurements based on a thermistor inserted into the heart. Because even minute amounts of ac "leakage" current could be fatal, batteries were used to completely isolate the instrument from the ac power line. During those years I learned a few valuable lessons on the use of batteries in electronics equipment.

First, though, a note on terminology. In rigorous usage, a "cell" is the most basic element, and has the minimum voltage for that sort of device. We gain additional voltage by connecting the cells in series and extra current by connecting them in parallel. To be strict, we would refer to the single entities as "cells" and multiple-cell entities as "batteries." But in common usage — where it's usually acceptable to be less rigorous — all cells and batteries are called "batteries." We'll follow that practice here.

Portable medical electronics equipment is powered with NiCds. These batteries have a nominal terminal voltage, at full charge, of 1.2 volts, except immediately prior to turn-on after a fresh charge, at which time the open-terminal voltage is 1.4 volts. Sometime after turn-on, however, the open-terminal voltage drops to the nominal value of 1.2 volts for the duration of operation. As the stored energy is used up, however, the terminal voltage drops lower.

NiCds will normally sustain 1000 charge-discharge cycles before becoming unusable. Manufacturers typically rate a battery unusable when the capacity of the battery drops below 80 percent of its original specified value.

The capacity of a battery is measured in ampere-hours — that is, the product of the current load (in amperes) and the time required to reach the officially designated discharge state. The NiCd is capable of delivering some tremendous currents: for example, the D cell (4 A-H) and F cell (7 A-H) can deliver short duration currents of 50 amperes or more. (This is why they're used in defibrillators, and why portable Amateur Radio transmitters can use them.)

Because they deliver huge currents, NiCds should be fused in order to protect printed wiring tracks, wires, and other conductors. I've seen copper foil pc tracks and an on/off switch smoked by a shorted capacitor across the dc line from a NiCd battery.

The amount of time that a battery will sustain its charge is a function of the discharge time, which in turn is determined by the amount of current drawn.

Figure 1 shows two different discharge scenarios: one for a current of 1/10 the A-H rating, and one for a current equal to the A-H rate. In **fig. 1A**, the battery will be fully discharged in 10 hours, while in **fig. 1B** discharge will occur in 1 hour. This particular chart is derived from the data published for a D cell rated at 4 A-H.

The standard cell ratings for NiCds are as follows:

Battery Size	A-H Rating
AA	0.4/0.5/0.7
C	2
D	4
F	7

As you can see, the AA cells are available in three ratings from 400 to 700 mA-H, depending upon the manufacturer and style.

You'll find plenty of variation from this chart, especially among consumer product quality (rather than professional quality) NiCd batteries. I've seen

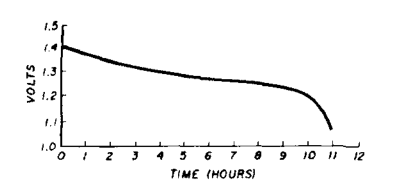


fig. 1A. NiCd battery discharge curve: Discharge current — 10 percent A-H rating.

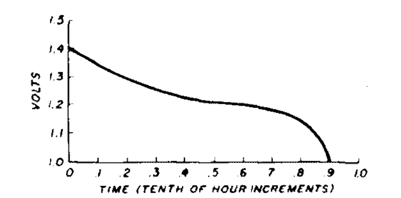


fig. 1B. NiCd battery discharge curve: Discharge current — 100 percent A-H rating.

C cells rated at both 1 and 1.2 A-H, and D cells rated at 2 A-H. I suspect that these are lesser cells dressed in C and D packages; one manufacturer's representative admitted to me that his consumer D cells were actually C cells inside of D packages!

This chicanery, of little consequence to most consumer electronics users, results in a lower cost product. But if you use these batteries in communications equipment, make sure that you get the correct A-H rating. It's been my experience that Gould brand cells are fully rated; others may require caution.

Some distributors play the rating game by quoting different discharge rates. One standard method of measuring A-H capacity is the amount of current required to discharge a cell to 1.0 volts in 1 hour. Some makers, however, define A-H capacity in terms of the 10-hour discharge rate normalized to ampere-hours. In analyzing **figs. 1A** and **1B**, you can see how this might result in a warm, fuzzy — but false — feeling of capacity.

The charging protocol for NiCds depends some what on the application and manufacturer. In general, though, the charge current must be at least A-H/20, and in many commercial consumer battery chargers it's often A-H/15. For most applications where you can control the charge rate, it's safe to use a charge rate of A-H/10. That is, charge the battery at a current not greater than 1/10 the ampere-hour rating. In addition, the battery must be charged to 140 percent of capacity, so a charge time of 14 hours is mandated. The general rule is: *charge at 1/10 ampere-hour rating for 14 hours.*

Some chargers are designed to fast-charge the battery in as little as 1 hour; most, however, demand 3 to 4 hours. Fast-charging should not be done unless the battery manufacturer recommends it. Even then, I'm a little cautious about fast-charging, having once seen a D cell explode during too-fast charging. NiCds can be dangerous, so follow the maker's recommendations carefully.

NiCds have finite shelf lives as well. Some users find that a battery charged, then stored, is unusable when it's eventually turned on. My old Wilson walkie-talkie suffered that fate several times. **Figure** 2 shows a storage discharge curve for a typical NiCd. As you can see, the battery or cell will be of questionable utility after only a few weeks' storage. The cure for this problem is a trickle charge during long-term storage at a rate between A-H/30 and A-H/50. Some commercial battery chargers have a switch that allows either A-H/10 regular charge rate or a A-H/30 trickle charge.

Another problem with NiCds is operating temperature and its effects on available capacity. As shown in **fig. 3**, the available current capacity is a function of temperature. As the temperature increases above room temperature (72 F, 25 C), the available capacity diminishes. I'd like to see some data on NiCd performance at cold temperatures.

NiCd "memory"

You'll hear a running debate about whether or not NiCds have or do not have a memory problem. In this context, memory means that a battery

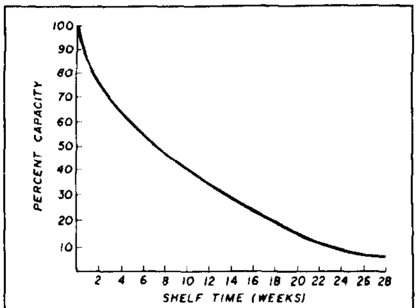


fig. 2. NiCds lose their charge even if unused.

won't allow deep discharge after repeated shallow discharges. For example, if a battery is repeatedly discharged in some particular application to only 80 percent of capacity, after a while it will "remember" the 80-percent level as the fully discharged point. The battery will then exhibit the fully discharged potential when the charge level is only 80 percent of fully charged. This makes the battery appear to have suffered premature failure. A NiCd battery with memory problems can sometimes be rehabilitated by repeatedly fully charging it, and then immediately deep-discharging it. Eventually the memory phenomenon should work itself out.

The best cure for the memory phenomenon is to avoid it. I have a friend who lives in constant pain, and as a result uses an electronic pulse generator called a "Transcutaneous Electronic Nerve Stimulator" (TENS) to keep the pain at a manageably low level. This physician-prescribed device runs on small NiCd batteries. When my friend complained that the $90 battery pack lasted only a few weeks, I questioned him further and found that he routinely placed the TENS in the charger every night, even though he didn't use it all the time. The TENS battery was obviously being routinely shallow-cycled, and consequently had developed a memory. I advised my friend to keep two battery packs available: one in an insulated bag in his briefcase, for use when the other one goes dead, and the other in the TENS itself. When the TENS battery is low, my friend simply swaps battery packs.

He used one battery pack for two years, and had been averaging at least a year on each — instead of six weeks.

When equipment is subject to routine maintenance, it's possible to keep the batteries healthy by following a certain routine. In most of the equipment I've serviced over the years, the manufacturer recommended that the batteries be periodically discharged and then recharged. The protocol for most is as follows:

- Fully charge the battery or cell.
- Discharge it fully with a resistor that draws a current of A-H/10 for 8 to 9 hours for multi-cell batteries, and 10 hours for single cells.
- Recharge the battery at the A-H/10 rate for 14 to 16 hours.

If the battery is not fully discharged, a phenomenon called "polarity reversal" may occur because not all cells have the same terminal voltage at any given time. It might happen that one cell will become charged backwards by the others in the series chain. For this reason, *multi-cell* batteries are discharged to only about 10 to 20 percent of capacity.

When a unit uses multiple cells to achieve higher voltage levels — and it's possible to remove those cells individually — it's better to discharge and recharge them one by one.

Batteries left in a discharged condition for a lengthy period of time may develop inter-element shorts: little whiskers (called "dendrites") grow from plate to plate, causing a short circuit. The cell potential drops to zero or near-zero, and the cell refuses to accept a charge. In some cases, we would have to regard the cell as lost and replace it. There are, however, some cells that can be salvaged from short circuits.

Figure 4 shows a revitalization circuit for shorted NiCd cells that works by vaporizing the internal dendrites that short the plates together. A known-good cell of the same type is placed across the shorted cell through a push-button or spring-loaded toggle switch. (It's important to use this type of switch instead of a regular switch . . . we don't want to keep the circuit

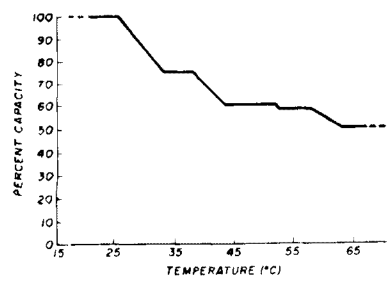


fig. 3. Elevated temperatures reduce NiCd performance.

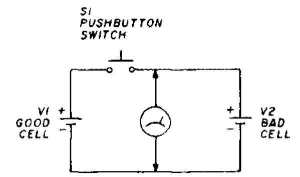


fig. 4. One method of revitalizing a "dead" NiCd cell.

closed for too long because an explosion could *result.*) Press the switch several times in succession, then measure the terminal voltage. If the current from V1 successfully vaporizes the dendrites inside V2, then the terminal voltage will rise.

CAUTION: wear safety goggles or glasses when performing this operation. NiCd batteries have been known to explode under high current, and it could conceivably happen when repairing a shorted cell. I've never seen it happen under these circumstances, but I wouldn't bet my eyesight on its never happening.

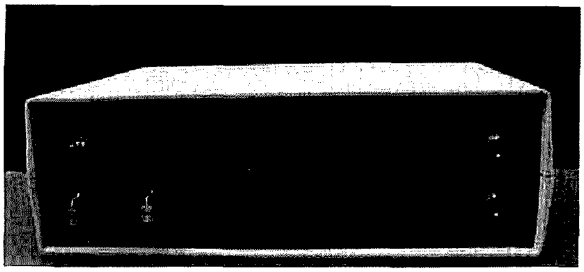
next month

In the final installment of this two-part series, we'll take a look at charging schemes for NiCd batteries. We'll also take a look at lead-acid and gel-cel batteries used to power mobile and portable Amateur equipment.

ham radio

the weekender

an improved RDF



The Dick Smith Electronics (DSE) Model K-6345 Radio Direction Finder (RDF) unit* has drawn considerable interest among transmitter hunters. The low price of this kit, compared with the cost of other commercial Doppler RDFs, has been its main attraction.

The direction finder consists of two assemblies — a control/display electronics section and the ASU or Antenna Switching Unit. The display has an electronic compass, which is a series of 32 LEDs arranged in a circle whose illumination is a function of the transmitted signal arrival angle. The unit has potential applications from 6 meters to 70 cm for both sport and serious use in volunteer enforcement as well as search and rescue efforts. It's intended to work with any fm receiver in the appropriate frequency range, including handhelds and scanners.

problem areas

After evaluating the DSE unit and comparing it with similar homebrew and commercial Doppler RDFs, I found several shortcomings. Voice or tone modulation on the signal being hunted caused a "spreading" of the direction indication, frequently causing it to light all the LEDs in the circle on modulation peaks; getting a good bearing on a signal with continuous tone modulàtion was nearly impossible. Noise created by the electronic antenna rotation sometimes obliterated signals that were not full quieting, or spread the indication further. In addition, parasitic reradiation in the antenna system worsened the effects of multipath on the indication.

I found the original design virtually useless for mobile hunting in urban areas because the display dashed around rapidly with no discernible trend. Though the Doppler RDF technique is easier to use in motion than beam/quad/loop schemes — and also averages out multipath indications — this was not the case with the DSE unit because of the problems cited above.

*Available from Dick Smith Electronics, Redwood City, California for $99.

By Joe Moell, K0OV, P.O. Box 2508, Fullerton, California 92633

Fortunately, there are several ways to improve the unit and make it a credible performer. Some of them have been mentioned briefly by the manufacturer in an addendum sheet now being supplied with the kit. I developed several others, including the fixes to the active filter stage described here. The modifications, all quite simple and involving little additional cost, are made in two areas, the Antenna Switching Unit (ASU) and the bandpass filter stage.

The instruction manual discusses the theory of how the Doppler effect is used for direction finding, but it gives no advice on how to install and use a Doppler RDF on a vehicle. Some practical hints on that topic are included later in this article.

the antenna unit

Electronic rotation of the antenna assembly is achieved by sequentially switching each of the four whip antennas to the receiver by the ASU. *Only one antenna is connected to the receiver at any one time.* The other three are disconnected by diodes D201-D204* in the ASU and shorted to ground by diodes D205-D208 at the antenna bases. Because these unused whips are grounded, they affect system performance by adding undesirable harmonic content and amplitude modulation to the induced Doppler signal. The effects of reflections from nearby terrain features are magnified by the reradiation. So even a small amount of multipath results in unreadable displays when the unit is used in motion.

The solution is to have the switched-off whips be electrically floating instead of grounded. Remove and discard the shunt diodes (D205-D208) at the bases of the four whips. Doing this won't adversely affect the operation of the ASU. There is 26 dB isolation from each switched-off whip base to the receiver using the shunt diode and 23 dB without it. The difference is insignificant.

The switched-off whips will still appear to be grounded if the coax lines to the ASU are an odd multiple of an electrical quarter wavelength. That's because a nonconducting diode in the ASU is trans-

*Component designations indicated are as used in K-6345 RDF kit and differ from customary *HR* nomenclature.

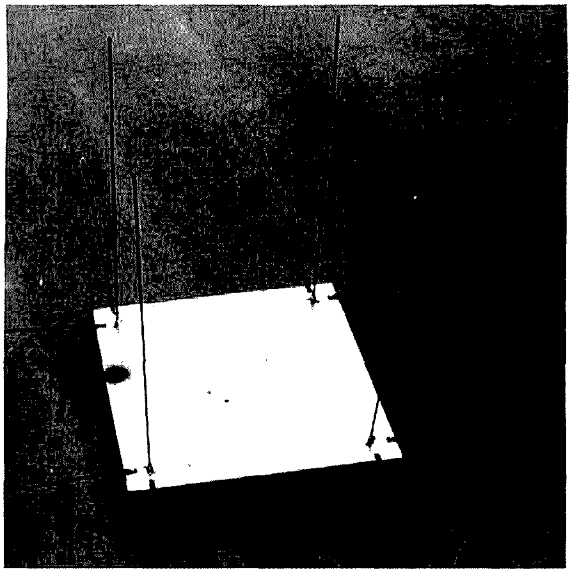


fig. 1. This antenna system is built in an aluminum chassis and uses bronze welding rod for elements. RCA phono plugs and jacks are used to attach the whips.

formed to an apparent short at the end of an odd quarter wavelength multiple line. For best results, change these lines to be exact electrical half wavelengths at the frequency of interest.

Be sure to take the velocity factor of the coax into consideration in the computation. For 2 meters, using ordinary polyethylene dielectric RG-58 (with a 66 percent velocity factor), the coax lengths should be 26-1/2 inches (or a multiple of that) from the antenna base to the ASU circuit board. This length includes the connector on the box and the coax from the connector to the board. For foam dielectric cables such as RG-8/X (with a 78 percent velocity factor), the length should be 31-1/2 inches for 2 meters. It's important that all four lines be of equal electrical length.

A one-piece antenna assembly like the one shown in **fig. 1** is easy to mount on the roof of a car with suction cups and nylon straps (not shown). Use an all-metal enclosure, such as an aluminum chassis and cover plate. The plastic ASU box supplied by DSE is acceptable if it's placed inside a larger metal enclosure like the one shown.

Other ways to configure the antenna system include setting an open wooden frame with individual ground planes in the back of a pickup, mounting a set of four vertical dipoles on a PVC pipe support, or using four individual mag-mount antennas on the vehicle roof. In any of these cases, the ASU board should be placed either inside a metal box or inside a plastic box that has been sprayed with conductive paint for shielding.

The short leads inside the ASU box from the four coax receptacles to the board should be changed to equal lengths of small coax, such as RG-174/U, replacing the bare wire provided. Alternatively, when the entire antenna system is housed in a metal enclosure such as shown in **fig. 1**, the four connectors can be deleted and the RG-58 lines can go directly from the antenna bases to the ASU board.

A good ground plane for the antenna system is very important. Eight radials are attached to the antenna base chassis with lugs as shown in **fig. 1**. The radials and the whips should be stiff enough that they don't flop around when in motion. Bronze welding rod (3/32 inch diameter) is ideal for this purpose; it accepts solder readily and is available inexpensively at welding supply stores.

Switching noise from the BA244 diodes supplied by DSE is objectionable because it can mask weaker signals. You'll notice an improvement by replacing D101-D104 with PIN types, such as Motorola MPN-3401. An equivalent part is available in the ECG and NTE replacement semiconductor lines as ECG-555

what is direction finding?

The classical method of direction finding employs a rotatable antenna and a receiver. Depending upon the antenna pattern and the detection method, the antenna is *slowly* rotated until either a maximum or minimum signal is detected.

Each antenna and receiver comprises one station. Two or three stations working from different locations are then able to compare bearings and determine an approximate location of the source. This process is known as triangulation.

A second method known as Doppler RDF uses a *rapidly* rotating antenna that in addition to receiving the main signal, introduces an *fm component* that is proportional to its speed of rotation. For example, as the antenna approaches the source, the frequency increases. As it rotates away from the source, the frequency decreases slightly. This is similar to the effect noticed as a train, with horn blaring, draws nearer. The tone rises and then diminishes. Note, however, that it's the phase — not the actual frequency of the tone — that contains information about the direction of arrival of the transmitted signal.

Instead of physically rotating the receiving antenna(s), an electronic switching method can be employed that in effect rotates the pattern and accomplishes the same purpose without moving parts. Practical Doppler RDFs sequentially switch four or more elements to simulate the single rotating antenna. Sometimes this technique is known as "pseudo-doppler."

and NTE-555. These diodes are In low-inductance packages with tabs instead of wire leads, and should be surface-mounted to the etch side of the ASU board, as shown in **fig. 2**.

optimizing the filter

The reason for "spreading" of the indication with modulation lies in the filter section. First of all, the *Q* of the switched capacitor filter section is set to 15 by the resistor values. This is far too low, giving poor voice rejection and a response time that is too rapid. Second, the peak in the filter response doesn't occur at exactly the detected Doppler tone frequency.

In a properly designed switched capacitor bandpass filter, the response peak is at an exact submultiple of the clock frequency. The filter peak should follow the clock input exactly, so that any drift in the antenna rotation frequency is tracked by the filter. Due to a characteristic of the MF5* filter IC, the peak will be offset by 0.615 percent if the two 10-k resistors (R16 and R17) are perfectly matched.

Such a good resistor value match is unlikely with the 5 percent resistors supplied. With unmatched resistors, the offset could be up to 10 percent. In the case of the evaluation unit, it was 7.1 percent. Any offset causes phase changes in the filtered Doppler signal when voice modulation and multipath cause amplitude changes in the input tone level. These phase changes result in erroneous changes in bearing on the RDF display.

Fortunately, it's easy to make significant improvements in the filter section. **Figure 3** shows the modifications and **fig. 4** indicates parts locations. First, raise the value of R12 from 150k to 2.7 megohms. This gives a filter *Q* of 270. Next, correct the offset problem by making the resistance at R17 0.615 percent (about 61.5 ohms) greater than R16.

Although it's possible to do this by choosing fixed resistors with a precision ohmmeter, there's an easier way that makes use of the greatly increased *Q* of the filter. Add a 1000-ohm variable resistor in series with R17. Since its adjustment is a bit touchy, a multiturn miniature trimpot is best. Glue it to the circuit board and wire it in; it will become a permanent part of the unit. Set the pot for zero ohms at first.

The pot is adjusted with the control unit hooked up to a completed antenna unit and VHF-fm receiver. Transmit an unmodulated test signal (from a separate transmitter) and measure the filtered df tone at pin 1 of IC5 (the MF5) with an oscilloscope or ac voltmeter.

If an ac voltmeter is used, put a 0.1 μF capacitor in series with the meter lead to prevent the dc level at pin 1 from obscuring the filtered df tone.

*This is a National Semiconductor part number. For more information, see the data sheet for the MF10, which is two identical MF5-type filters in one package.

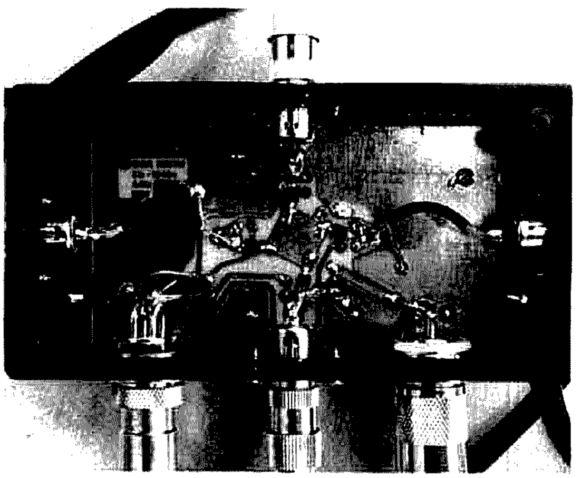


fig. 2. Interior of the ASU enclosure showing the equal length RG-174/U coax jumpers and NTE-555 PIN diodes, which replace the BA244s.

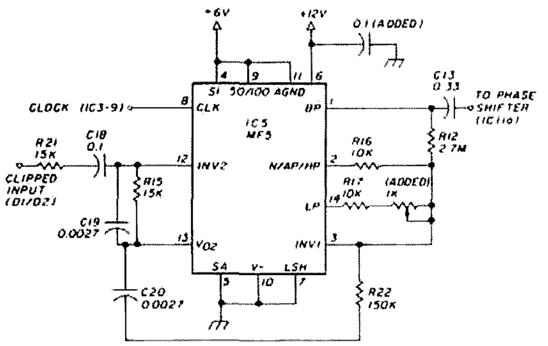


fig. 3. Modified bandpass filter schematic.

Slowly adjust the pot for maximum amplitude of this df tone. The test signal must be unmodulated and full quieting or it will be difficult to find the peak. The setting of the pot will depend on how well matched R16 and R17 are. If the level goes down instead of up as the pot resistance is increased, then R17 is already more than 62 ohms higher than R16. In that case, swap resistors at R16 and R17, set the pot to zero ohms, and try readjusting again.

It's important to mention that the Doppler tone into the control unit does *not* vary in frequency. Doppler shift introduces instantaneous change in frequency of the received rf signal, causing a tone to come out of the receiver's discriminator in addition to any other fm modulation on the signal (voice, for example). The phase of this tone is important — not the frequency, which is the same as the antenna rotation frequency. If the tone changes in frequency, it's because the

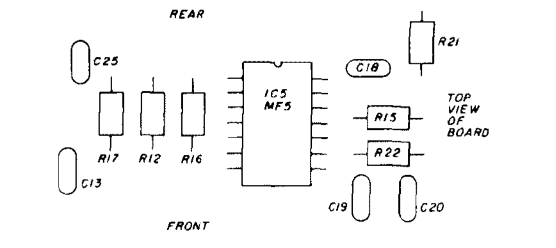


fig. 4. Parts layout of the bandpass filter. Early units do not have reference designators silk-screened on the board.

master oscillator (IC2) drifts. That's why a switched capacitor bandpass filter is ideal for this application. When driven from the same clock, it tracks.

To improve digital noise rejection and minimize the chance of oscillation, filter the Vcc line to the MF5 with a 0.1-μF miniature ceramic capacitor. Put it on the etch side of the board at pins 6 and 7 with very short leads.

Increasing the value of R12 to 2.7 megohms provides high *Q* filtering without detrimental effects from clipping in the filter or phase shifter stages. Although unlikely, it's possible that such a high value on some units might upset the MF5 output biasing due to its input offset currents. It could also cause the MF5 to oscillate. If either occurs, lower the value of R12 as required. There were no such problems in my evaluation unit over a wide temperature range. The dc voltage at pins 1 and 14 of the MF5 with no Doppler signal input will be within ± 1 volt of the dc voltage at pin 11 if all is well.

checkout

Be very careful to confirm that the antenna is electronically rotating in the proper direction. It's easy to get it "backwards" so that the antenna unit and the display rotation are in opposite directions. If the antenna unit is rotating backwards, the unit will have a left/right (90/270 degrees) reversal of bearings when calibrated on a reference signal in front of the vehicle (zero degrees). I have seen this mistake in two kit builders' units. The four-pin shielded control cable must be wired pin 1 to pin 1, pin 2 to pin 2, etc.

The DSE instruction manual does not show the exact wiring of the four-pin antenna control cable connectors, nor does it show how to check for proper antenna rotation. There are two ways to do this after the unit is completed. When the instructions tell you to connect control cable pins to test point A and observe the 0, 90, 180, and 270-degree LEDs, connect test point A to the whips themselves in succession, not the control cable pins. This verifies wiring of the antenna cables as well as the control unit and ASU. Antennas are numbered 1 to 4 in clockwise order as viewed from the top of the antenna system.

You can also use an oscilloscope to observe that the control pulses proceed from antenna to antenna in clockwise order. Look at the waveform at each whip. It's low (-0.6 volts) when the whip is on and nearly +12 volts when the whip is off. Sync the scope on whip No. 1 and observe that No. 2, No. 3, and No. 4 follow in proper sequence.

calibration

The DSE manual suggests an obvious method of calibrating and checking a VHF Doppler: just walk around the vehicle with a transmitting handheld and adjust the calibration control on the front panel for correct bearings. But that method won't give optimum accuracy. It's adequate for only a very rough check. Nearby reflections and the near-field characteristics of the signal cause inconsistent and inaccurate indications.

Repeaters or strong base stations that are a mile or more away give better results. The signal should be strong and the path should be unobstructed. The antenna should be in a relatively clear area. For a mobile system, try a large, empty parking lot. Turn the antenna unit or drive the car around in a circle to verify that the bearing is reasonably consistent. Again, don't expect super accuracy on this check, particularly if the repeater is many miles away.

For mobile use, the best final calibration is done with the vehicle in motion. Drive slowly down a long stretch of straight, vacant road with a friend a quarter mile or so ahead, transmitting. With the other vehicle keeping pace ahead of you, adjust the calibration control until the top LED (zero degrees) is on. Now pass the signal source; after you pass, the bottom LED (180 degrees) should be on. Doing the calibration while in motion helps average out the local reflections which can throw off stationary bearings.

The calibration control on the front panel allows for correcting the display to match the orientation of the antenna unit. It also compensates for differing phase delays of the df tone through different receivers. Unfortunately, the control has less then $\pm$ 90 degrees of range. The display can be rotated in 90-degree steps for more calibration range by rotating the antenna connectors.

For example, let's say that with the signal straight ahead, the calibration control swings the indication from 190 to 330 degrees, but can't get it to zero degrees where we want it. The indication can be rotated 90 degrees clockwise by connecting antenna No. 4 to the D201 input, antenna No. 1 to the D202 input, and so forth. Now the calibration control covers the range 280 to 60 degrees for a straight-ahead signal, which includes the desired zero degree indication.

using a Doppler RDF in a vehicle

As with any RDF system, it's important to get to know the gear well before taking it out for an actual hunt. To become familiar with the unit, try to hunt local known signals for practice. The instantaneously updating display of a Doppler RDF unit is easy to read, but there are some subtleties in its interpretation. Remember that it can indicate only one bearing for each rotation of the antenna. When reflected signals approach the strength of the direct signal, the result in a Doppler RDF is a bearing indication that is incorrect for both the direct and reflected sources.

The best strategy is to keep moving and watch the general trend of the indications. By moving along, the effects of close-in reflections are averaged out. Take the time to learn to read the display and listen to the audio out of the speaker in different types of terrain and with different transmitting sites, power, and antennas.

As you drive around you'll note that the df tone in the receiver audio changes quality from smooth to "raspy." *Raspiness of the tone generally indicates that multipath is present.* Multiple Doppler signals are summing together in a random fashion, giving a high harmonic content to the resulting df tone. At worst the tone seems to jump in pitch by exactly one octave, and may stay high for a block or so. Put your greatest trust in the bearings indicated when the tone isn't raspy or an octave high.

limitations of Doppler RDF gear

Many newcomers to T-hunting have unreasonably high expectations of the many available Doppler RDFs. They think they'll be unbeatable in the local T-hunts. They also imagine that several Doppler RDFs linked for triangulation will locate jammers with pinpoint accuracy from dozens of miles away. Experienced hunters know that neither is true.

Tests by manufacturers of highly sophisticated commercial and military Doppler RDF systems such as Watkins Johnson, and by long-term users such as the U.S. Coast Guard Auxiliary, have shown that even the very best four-antenna designs have significant inherent inaccuracies when used for medium-distance bearings at fixed sites. Parasitic effects in the antenna system can cause an error of up to $\pm$ 5 degrees around the circle when the unused antennas are properly floated or terminated, and far more if they're not. The readout steps are 11.25 degrees, limiting resolution. On top of all this, atmospheric effects cause additional error. This error can be 15 degrees or more, varying with time of day. It is greatest if part of the path is over land and part over water.

Ten degrees of error at 10 miles causes the line of bearing to miss the source by 1-3/4 miles. Triangulation from three high fixed sites 20 miles apart with a $\pm$ 10 degree error margin will produce an area of uncertainty 13.8 square miles in size. This is where the mobile hunters come in; when it comes to pinpointing the source of malicious QRM and gathering credible evidence, there's no substitute for a cadre of mobile hunters who've practiced their skills and become familiar with their gear.

Mobile hunting with any type of RDF setup can be a difficult task when the hunted operator uses sufficient cunning. Competitive hunters using Doppler RDF sets in southern California generally don't do better than teams using vehicle-mounted beams or quads. But the Doppler RDF's ease of use and rapid updating make it a good choice, particularly when you're hunting alone or hunting a mobile jammer. Having high accuracy is less important in a vehicle because the RDF is being used primarily as a "homing" device.

On the other hand, there are situations when a Doppler RDF isn't the best choice for the task. If the signal is very weak, the lack of gain and the residual switching noise in the Doppler antenna system will make it hard to get accurate indications. If the hunted signal is horizontally polarized, reflected signals (often vertical) will be emphasized with respect to the direct signal into the vertical whips. Again, it will be much more difficult to get an accurate bearing. In those situations, a high gain beam or quad, properly polarized, is a better choice for getting a high-accuracy bearing on the signal.

conclusion

A properly operating Doppler RDF really shines when used in a vehicle for closing in on a fixed or moving RF source. With the modifications suggested in this article, the Dick Smith K-6345 RDF does a respectable job without the need for major redesign. I'd like to hear from other users who discover further improvements.

acknowledgments

I want to thank fellow T-hunters J. Scott Bovitz, N6MI, and Jorge DiMartino, KI6MD, for providing information and equipment that assisted in the evaluation and improvement of this unit. Also thanks to the dozens of transmitter hunters in my area who provide challenging hunts for testing of this and other RDF systems.

bibliography

Reprinted from *Transmitter Hunting — Radio Direction Finding Simplified*, (No. 2701), copyright 1987 by Tab Books, Blue Ridge Summit, Pennsylvania 17214. Available from Ham Radio's Bookstore, Greenville, NH 03048. $17.95 plus $3.50 shipping and handling.

ham radio

locator field list

Compiled since 1982, this list uses the Maidenhead Locator system, adopted by IARU Region 2 and the ARRL in 1983. The largest unit in the system is a *field*. A field measures 20 degrees in longitude by 10 degrees in latitude, and is designated by two letters – for example, *RJ*. There are 324 fields on the earth's surface; the goal is to work all of them on the same band. This is a very difficult task – much more difficult than working all DXCC countries, partly because 54 of the fields are areas on the oceans and partly because very few stations know their own field designators. (Though it may be a long time before locator information becomes part of each QSO, we should all work towards this goal. By exchanging only six characters, such as JO99DK, we can identify the position of our stations within ±10 km anywhere on earth.)

The middle unit of the locator is called a *square*. To help Amateurs identify their own and other squares, I've produced a 24-page atlas that shows all 32,400 squares worldwide. The atlas is available from Ham Radio's Bookstore ($4.00 plus $2.00 shipping and handling) or directly from me for six IRCs plus a large SASE (minimum size: 9 x 12 inches). The atlas also contains computer programs for determining both locator data (from longitude and latitude) and distance and direction between two locators.

All readers are invited to take part in this competition. The list covers all bands – from 1.8 MHz to 10 GHz – and includes the top 20 operators on each band. The rules are very simple and are presented at the bottom of each list, which is compiled four times per year.

If you'd like to participate, send your information to me as soon as possible after the following dates as possible: March 31, June 30, September 30, and December 31.

By Folke Rosvall, SM5AGM, Vasterskarsringen 50, S-184 00 Akersberga, Sweden

AJ	BJ	CJ	DJ		OJ	PJ	QJ	RJ
AI	BI	CI	DI		OI	PI	QI	RI

LOCATOR FIELD LIST

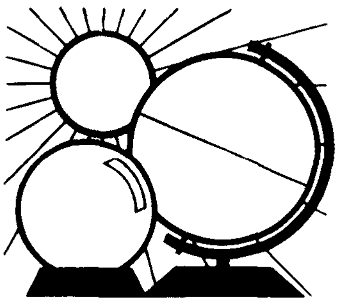
1987-03-31, COMPILED BY SM5AGM (JO99DK). WHO WILL BE THE FIRST RADIO AMATEUR TO WORK ALL 324 FIELDS ON THE SAME BAND?

1.8 MHZ	1 W1JR	FN	68 870330	2 SM3CWE	JP	51 861231	3 SM6CTO	JO	33 850127	4 SM0LH	JO	5 860322	5 SM4JXG	JO	3 861231
3.5 MHZ	1 SM3CWE	JP	129 861231	4 SM7WT	JO	68 850129	7 SK6AW	JO	44 870331	10 SM0LH	JO	8 860322			
	2 W1JR	FN	102 870330	5 SM0HTO	JO	64 851230	8 SM6INC	JO	29 860331	11 SM4JXG	JO	7 861231			
	3 SM0CCE	JO	79 850122	6 SM5CAK	JO	56 860921	9 SM3CVM	JP	19 861012						
7 MHZ	1 SM3CWE	JP	141 861231	4 SM7WT	JO	97 850129	7 SK6AW	JO	50 870331	10 SM0LH	JO	15 860209	13 9V1RH	OJ	6 861211
	2 SM0CCE	JO	138 850122	5 SM7PKK	JO	86 870322	8 SM0HTO	JO	47 851230	11 SM5CAK	JO	11 860921			
	3 W1JR	FN	119 870330	6 SM6INC	JO	73 860331	9 SM3CVM	JP	43 861012	SM4JXG	JO	11 861231			
10 MHZ	1 W1JR	FN	43 870330	4 SM6INC	JO	15 860331	7 SM6MSG	JO	10 850930	10 SM0HTO	JO	7 851230	13 SM5CAK	JO	3 860921
	2 9M2FP	OJ	31 861220	5 SM3CWE	JP	13 861231	8 SM0LH	JO	9 860322	11 SM7BDB	JO	5 850922			
	3 SM5FUG	JO	21 860912	6 SM5ACQ	JO	11 870331	SM4JXG	JO	9 861231	12 SM5PAX	JO	4 850930			
14 MHZ	1 SM3CWE	JP	221 861231	4 SM0CCE	JO	186 850122	7 SK6AW	JO	134 870331	10 SM5CAK	JO	73 860921	13 SM4JXG	JO	37 861231
	2 SM7WT	JO	201 850331	W1JR	FN	186 870330	8 SM6INC	JO	126 860331	11 SM0LH	JO	57 860212			
	3 SM0HTO	JO	192 851231	6 W6DU	CM	147 860526	9 SM5ACO	JO	122 850930	12 SM5FBL	JO	44 850126			
18 MHZ	1 SM5ACO	JO	12 870331	3 SM7BDB	JO	8 850922	5 SM0LH	JO	5 860322	SM0HTO	JO	3 851230			
	2 SM6INC	JO	9 860331	4 SM4JXG	JO	7 861231	6 SM5PAX	JO	3 850930	8 SM3CWE	JP	2 861231			
21 MHZ	1 SM3CWE	JP	158 861231	4 SM6INC	JO	109 860331	7 SM0HTO	JO	52 851230	10 SM3CVM	JP	24 861012			
	2 SM0CCE	JO	153 850122	5 SM5ACO	JO	95 850930	8 SM0LH	JO	44 860209	11 SM5CAK	JO	10 860921			
	3 SM7WT	JO	131 850129	6 SK6AW	JO	72 870331	9 SM4JXG	JO	38 861231						
24 MHZ	1 W1JR	FN	25 870330	3 SM0HTO	JO	5 851230	5 SM5ACQ	JO	4 861202	7 SM0LH	JO	1 860209			
	2 SM6INC	JO	8 860331	SM4JXG	JO	5 861231	6 SM7BDB	JO	2 850922	SM3CWE	JP	1 861231			
28 MHZ	1 DF2NJ	JO	159 851111	5 SM0CCE	JO	126 850122	9 SM0HJV	JO	93 860917	13 SM0JXA	JO	21 861101			
	2 SM6LIF	JO	143 850909	6 SM3CWE	JP	123 861231	10 SM5ACQ	JO	53 850930	14 SM4JXG	JO	12 861231			
	3 SM0HTO	JO	139 851230	7 SM6INC	JO	111 860331	11 SK6AW	JO	47 870331	15 SM5CAK	JO	9 860921			
	4 SM7LXV	JO	127 850630	8 SM7WT	JO	108 850129	12 SM0LH	JO	32 860212	16 SM3CVM	JP	5 861012			
50 MHZ	1 WA1OUB	FN	46 860801	2 N0LL	EM	41 861106	W1JR	FN	41 870330	4 KA9MGR	EN	16 860331	5 JQ1GTC	QM	5 861212
144 MHZ	1 SM7BAE	JO	45 870214	SM2GGF	KP	37 850622	9 YU3ZV	JN	32 831231	OZ1EME	JO	31 841224	17 OH7PI	KP	28 831231
	2 VE7BQH	CN	42 870113	6 Y22ME	JO	36 861231	WA1JXN	DN	32 840508	14 SM4IVE	JO	30 840609	W5UN	DM	28 840428
	3 K1WHS	FN	38 840930	7 YU3WV	JN	35 870331	F6CJG	JN	32 850110	WA4NJP	EM	30 840903	KD8SI	EM	28 850116
	4 DL8DAT	JO	37 850304	8 SM4GVF	JO	34 860930	12 F6BSJ	JN	31 840903	16 KB7Q	DN	29 851231	OK1MS	JO	28 850331
220 MHZ	1 W1JR	FN	10 870330	2 KA9MGR	EN	4 860331									
432 MHZ	1 K2UYH	FN	33 850331	5 WB5LUA	EM	28 840428	9 VE4MA	EN	23 830331	13 K1FO	FN	19 850318	17 DF9CY	JO	10 830627
	DL9KR	JO	33 861001	6 W7GBI	DM	27 840505	10 SM6CKU	JO	21 821231	Y22ME	JO	19 861231	18 OZ3ZW	JO	7 850630
	3 YU1AW	KN	30 860407	7 OK1KIR	JN	26 850221	SO1MN	JO	21 860617	15 SM0DJW	JO	18 851231	SM6FYU	JO	7 860331
	4 W1JR	FN	29 870330	SM3AKW	JP	26 861231	12 OH6NU	KP	20 821231	16 W7HAH	DN	12 860314	20 SM0BYC	JO	6 841231
902 MHZ	1 W1JR	FN	2 870330												
1.3 GHZ	1 K2UYH	FN	20 850331	W7GBI	DM	13 840505	OE9FKI	JN	7 850331	SM0DJW	JO	5 851231	W1JR	FN	4 870330
	2 OK1KIR	JN	17 850221	6 SM6CKU	JO	12 821231	OZ3ZW	JO	7 850630	SM3AKW	JP	5 861231	18 K1FO	FN	3 850318
	3 OE9XXI	JN	16 850331	7 YU1AW	KN	11 860407	11 DL7YC	JO	6 840411	15 SM0PYP	JO	4 830331	SK5EW	JO	3 850331
	4 WB5LUA	EM	13 840428	8 W6YFK	CM	7 840506	12 SM6HYG	JO	5 821231	SM4AXY	JO	4 831231	SM6NJC	JO	3 850630
2.3 GHZ	1 W4HHK	EM	4 850304	3 SM6HYG	JO	3 830331	5 OK1KIR	JN	2 850221	7 PA0SSB	JO	1 821231	WA4HGN	EM	1 840505
	OE9XXI	JN	4 850331	W6YFK	CM	3 840506	W1JR	FN	2 870330	WB5LUA	EM	1 840428	OZ1CFO	JO	1 850826
3.4 GHZ	1 SM6HYG	JO	1 850914												
5.7 GHZ	1 SM6HYG	JO	1 850914	OZ1CFO	JO	1 850930									
10 GHZ	1 SM0DJW	JO	2 850630	YU1AW	KN	2 860205	3 SM6HYG	JO	1 850914	SM7ECM	JO	1 860930	W1JR	FN	1 870330

This list shows the number of fields worked according to the Maidenhead Locator system. A field is a block of 20° (longitude) × 10° (latitude). Rules: 1. All fields must have been worked via passive reflectors. 2. All stations involved must be on the earth's surface. 3. QSL cards are not required if you are sure that the other station considers the QSO complete. 4. All QSO's must have been worked from points within a circle of 1000 km radius. 5. There is no starting time for contacts to be eligible. A world map showing the 324 fields can be found in "The Radio Amateur's World (Locator) Atlas", that normally should be available at your national amateur radio society.

Compiled quarterly since 1982, the list shows the situation on March 31, June 30, September 30 and December 31 at 2400 UT. Please send your info as soon as possible after each date to SM5AGM, Folke Rosvall, Vasterskarsringen 50, S-184 00 Akersberga, Sweden. Tel. 0764-27638.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

summer thunderstorm noise

At any given moment an estimated 3600 thunderstorms are in progress around the world. They can be classified as air mass, frontal, or orographic, depending on how they are formed.

The main source of summertime QRN is the air mass thunderstorm, which builds up from the sun's heating the ground and the air above it. Most air mass storms form in afternoons when the humidity is above 50 percent, and last into the night before cooling off enough to dissipate. Air mass thunderstorms linger for several days until rain releases their moisture or they slowly move on. During the evening DXing hours, air mass thunderstorm QRN may limit the usefulness of low-band signals to local ragchewing and rule out, for the most part, weak-signal DX. This QRN, propagated from the equatorial land regions, or closer, increases the overall average noise level on the 80- and 160-meter bands which — except for a small peak at about 10 MHz — decreases as frequency is increased.

The noise can be minimized by careful operating practices. First, try to decrease the receiver bandwidth. You can go narrower until the signal you are demodulating becomes so distorted that readability is affected.

Then, by taking advantage of the directional properties of beam antennas (either parasitic or driven), you can improve overall signal-to-noise ratios by literally steering clear of the major noise source locations. The tropical areas where the noise is mainly generated are concentrated over the land masses. Consulting a world map, look from your QTH toward land mass areas between the equator and the 23rd degree meridian. From the East Coast of the United States, this would be parts of Africa (longitude 10 degrees West); from the southern states, parts of Central America (longitude 75 degrees West); and from the western United States, Southeast Asia (longitude 120 degrees East). If you can avoid pointing your beam at these areas, you can help minimize noise pickup. In fact, if you can get the back of the antenna pointed in that direction, you can use the front-to-back ratio (typically 15 dB) to further decrease noise pickup. This may mean working a DX country over the long path or over the Pole. If the ionosphere will support propagation in that direction and no geomagnetic field disturbance is occurring, you may find that the solution to some of the summer noise problems.

last-minute forecast

The lower frequency bands are expected to be at their best the first two and a half weeks of the month. Solar flux should be low at this time, leading to better signals on east-west paths to Europe and Japan. Geomagnetic disturbances, possible from the 6th to 10th, may reduce MUFs on these paths so that only 80 and 160 meters are available, showing weak signals and QSB. The last two weeks of the month are the higher frequency bands' time to shine. Solar flux is expected to be highest then; MUFs should also be highest, making long-skip possible at this time. Of course, this is the month when numerous short-skip sporadic E openings are possible, with their subsequent positive effect on the higher bands. Check WWV at 18 minutes after the hour or the Space Environment Services Center (SESC) computer bulletin board (303 497-5000) to verify the solar and geomagnetic data.*

A full moon will occur on the 11th; perigee (closest approach of the moon) is also on the 11th. The Aquarids meteor shower begins on July 18, peaks on the 28th, and lasts until August 7. (All dates are approximate, but close.) The radio-echo rate at maximum is about 34 per hour.

band-by-band summary

Six-meter paths will open for half an hour to a couple of hours on some days around local noon. Sporadic E propagation will make this short-skip path possible out to nearly 1200 miles per hop.

Ten, fifteen, twenty, and thirty meters will support DX propagation to most areas of the world during the daylight hours and into the evening with long-skip out to 2000 miles per hop. Sporadic E short-skip will also be available on many days for several hours around local noon. The direction of propagation will follow the sun across the sky: east in the morning, south at midday, and west in the evening. Long daylight provides many hours of good DXing. Solar flux is low this year, so daytime absorption allows higher signal strengths than usual on these bands during this month.

Thirty, forty, eighty, and one-sixty meters are the nighttime DXer's bands. On many nights, 30 and 40 meters will be the only usable bands because of thunderstorm QRN. Try the pre-dawn hours for best DX. The direction of propagation follows the darkness path across the sky: to the east in the evening, south around midnight, and toward the west in the pre-dawn hours. Skip distances will decrease to 1000 miles. Sporadic E openings will be observed most frequently around sunrise and sunset. These may be the only signals getting through the noise in the evening. Once again, because of the low solar flux, daytime DX — particularly in the mornings — may be good this month.

---

*See "DX Forecaster," May, 1987, page 105.

WESTERN USA

GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	20	30	20	12	20*	12*	12*	15
0100	6:00	20	*30*	*20*	12	20	10	10	15
0200	7:00	20*	*30*	*20*	15	20	10	10	15
0300	8:00	20*	*30*	*30*	20	20	10	10	15
0400	9:00	20	*30*	*30*	20	30	12*	12*	15
0500	10:00	20	20	*20*	20	30	12	12	15
0600	11:00	20	20	15	20	30	12	12	20
0700	12:00	20	20	15	*20*	30	12	15	20
0800	1:00	20	*30*	20	*20*	30	15	20	20
0900	2:00	30	*30*	20	*30*	40	15	20	20
1000	3:00	*30*	20	20	*30*	40	20	20	20
1100	4:00	*30*	20	20	*30*	*40*	20	20	*30*
1200	5:00	*30*	20	15	20	*40*	20	20	*30*
1300	6:00	20	20	12	20	*40*	*20*	*30*	*30*
1400	7:00	20	20	12	15	*40*	*20*	*30*	30*
1500	8:00	20	20	12	15	*40*	*20*	*30*	*30*
1600	9:00	20	20	10	15	*40*	*30*	*30*	*30*
1700	10:00	20	20	10	12	30	20	*30*	*30*
1800	11:00	*30*	20	12	12	20	15	*30*	30
1900	12:00	*30*	20	12	12	20	15	20	20
2000	1:00	*30*	20	15	12	20	12	15	20
2100	2:00	30	20	20	10	20*	12	12	20
2200	3:00	20	20	20	10	15	12	12	20
2300	4:00	20	20	20	12	15	12	12	20
	JULY	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN

MID USA

GMT	MDT	N	NE	E	SE	S	SW	W	NW	CDT
0000	6:00	20	20	20	12	20	10	10	15	7:00
0100	7:00	20	*30*	*20*	12	20	10	10	15	8:00
0200	8:00	20*	*30*	*30*	15	20	10	10	15	9:00
0300	9:00	20	*30*	*30*	20	30	12	12*	15	10:00
0400	10:00	20	*30*	*30*	20	30	12	12	20	11:00
0500	11:00	30	*30*	*30*	20	30	12	12	20	12:00
0600	12:00	*30*	30	*30*	20	30	12	12	20	1:00
0700	1:00	*30*	20	30	*20*	30	15	15	20	2:00
0800	2:00	*30*	20	20	*20*	40	15	15	20	3:00
0900	3:00	30	20	15	*30*	40	20*	20*	*30*	4:00
1000	4:00	*20*	30	15	*30*	*40*	20	20	*30*	5:00
1100	5:00	20	20	12	20	*40*	20	20	*30*	6:00
1200	6:00	20	20	12	20	*40*	20	30	20	7:00
1300	7:00	20	20	12	15	*40*	*20*	*30*	20	8:00
1400	8:00	20	20	12	15	*40*	*20*	*30*	20	9:00
1500	9:00	20	20	12	15	*40*	*30*	*30*	*30*	10:00
1600	10:00	20	20	10	12	30	*30*	*30*	*30*	11:00
1700	11:00	20	20	10	12	20	20	*30*	*30*	12:00
1800	12:00	30	20	12	12	20	15	*30*	20	1:00
1900	1:00	*30*	20	12	12	20	15	20	20	2:00
2000	2:00	*30*	20	15	12	20	12	15	20	3:00
2100	3:00	*30*	20	20	10	20	12	12	20	4:00
2200	4:00	30	20	20	10	20	12	12	20	5:00
2300	5:00	20	20	20	12	20	12	12	20	6:00
		ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN	

EASTERN USA

GMT	EDT	N	NE	E	SE	S	SW	W	NW
0000	8:00	20	20	20	12	20	10	10	15
0100	9:00	20	20	20	12	20	10	10	20
0200	10:00	20	*40*	*20*	15	30	12*	10	20
0300	11:00	20	*30*	*30*	20	30	12	12*	20
0400	12:00	30	*30*	*30*	20	30	12	12	20
0500	1:00	*30*	*30*	*20*	20	30	12	12	20
0600	2:00	*30*	*30*	20	20	30	15	15	20
0700	3:00	*30*	*30*	20	*20*	40	20*	15	*30*
0800	4:00	20	30	*20*	*20*	*40*	20	20	*30*
0900	5:00	20	20	20	*30*	*40*	20	20	*30*
1000	6:00	20	20	15	*20*	*40*	20	30	20
1100	7:00	20	20	15	20	*40*	20	30	20
1200	8:00	20	20	12	20	*40*	20	30	20
1300	9:00	20	20	12	15	*40*	*20*	*30*	20
1400	10:00	20	20	12	15	*40*	*20*	*30*	20
1500	11:00	20	20	10	12	*40*	*30*	*30*	*30*
1600	12:00	20	20	10	12	30	*30*	*30*	*30*
1700	1:00	20	20	10	12	20	20	*30*	*30*
1800	2:00	20	20	12	12	20	15	*30*	20
1900	3:00	30	20	12	12	20	12	15	20
2000	4:00	*30*	20	15	10	20	12	12	20
2100	5:00	*30*	20	20	10	20	12	12	20
2200	6:00	30	20	20	10	20	12*	12	20
2300	7:00	20	20	20	12	20	10	10	20
		ASIA FAR EAST	EUROPE	S. AFRICA	CARIBBEAN S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN

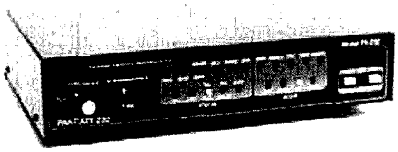
The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

product REVIEWS

the versatile PAKRATT

Amateur Radio is really dozens of hobbies in one, with communication by radio the common thread. Some of us are dedicated to only one aspect — DXing, for example. Others want to sample many areas. If you're one of the latter, and have an interest in digital communications, the AEA PK-232 may be for you, particularly if you already have a computer with an RS-232 serial port.



The PK-232 works on Packet, AMTOR, RTTY, and CW on both hf and VHF. By the time you read this, AEA will be shipping an upgrade kit that will let you add software for decoding weather facsimilie signals, too.

When RTTY was young, I had a teleprinter that weighed more than I did. With the advent of the microcomputer revolution, RTTY has become much simpler — nowadays it doesn't take much more than a computer and an appropriate interface. One of the more versatile interface designs is the AEA PK-232 Controller. Weighing in at about 3 pounds, it decodes Packet, CW, RTTY, and AMTOR signals. Connect it to any computer with an RS-232 serial port, and you're in the digital end of ham radio.

The PK-232's operating manual covers just about anything you need to know, including the standard advice to "Read the entire manual before you begin . . . ." What ham is ever going to do that? Fortunately, there's a section titled "Quick Start Installation," and that's where I began. The instructions on how to connect the PK-232 to my pc clone and to my radio are clear and easily followed.

The manual also includes a helpful appendix of instructions for connecting the PK 232 to several of the most popular radios. Though this appendix wasn't referenced in the Quick Start chapter, I found it on my own *after* I'd hooked up my handheld.

For a computer to act as a terminal, a terminal emulation program is required. I began with a 300-baud Dumb Terminal program. The PK-232 defaults to 1200, but I sent a couple of asterisks and the PK-232 adjusted to 300 baud automatically. (It handles 110 to 9600 baud, with the rate set by command.)

Using the cables supplied, I hooked the Pakratt to my VHF handheld. With just a Rubber Duck for an antenna, I was able to copy one side of a QSO. (I'll use the call "W4AAA" as an example.) When the QSO ended, I typed "C W4AAA" and a couple of seconds later my screen showed "*** CONNECTED W4AAA"! That was almost as good as my very first QSO, (a l-o-n-g time ago.) It was brief. I "DISCONNECT-ed" and read more of the manual, discovering that I needed three small flashlight batteries in the unit to make sure it remembered my call and my choice of baud settings as well as other parameters.

Hooked up to an outside whip, I could hear several stations on the handheld, so I tried connecting to myself through a digipeater. Any Packet station, of course, can act as a digipeater (unless it's told not to), so I typed in "C VE3ZL VIA W4AAA" and got "*** CONNECTED." I checked six or seven more stations and found that two or three of them were accessible as digipeaters.

In my ordinary Amateur operating, I do a lot of listening. The same was true when I started using the PK-232. A front panel switch lets you switch between two radios at will (in my case the VHF handheld and my SSB hf rig), so after listening to Packet for awhile on 145.01 MHz, I switched to the hf rig and copied some hf Packet on 20 meters. I was pleasantly surprised to find how easy it was to tune hf signals using the front panel bargraph LED indicator. And the PK-232's ability to copy weak-signal CW was better than I expected it would be.

Operating the PK-232 is fun, and although it's easy to go from any one mode to another, I find that most of my operating is on RTTY on 20 or Packet on 2 meters.

If you're already active on Packet, you may have noticed a message about the PK-232 on some bulletin boards indicating that the wide shift (1000 Hz) used by the PK-232 in RTTY mode isn't authorized by the FCC. *This is not so.* Part 97.69 (a)(2) of the lastest FCC rules permits 1000 Hz shift — so not to worry!

The PK-232 uses a Z-80 microprocessor, with software in PROM's. Twenty indicator LED's on the front panel let you keep tabs on what's going on.

The PK-232 is priced at $319.95 (Amateur Net). It takes 12 VDC at about 0.7 amp. A power adapter is available for $25.00.

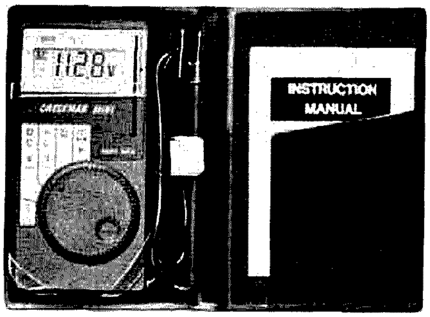
For more details, contact Advanced Electronic Applications, Inc., P.O. Box C-2160, Lynnwood, Washington 98036.

— VE3ZL

Circle #301 on Reader Service Card.

shirt pocket multimeter

Like most Hams, I'm a sucker for neat little gadgets. So when Eaglestone, a division of Siber Hegner of North America, sent me one of their new Ishii Checkman DM-1000 multimeters for review, I jumped at the opportunity.



Over the years I've used plenty of different multimeters — from the heaviest analog, drop-'-em-from-the-Empire State-Building-and-they'll-still-work-units to handheld models with digital LCD readouts. What makes the Ishii Checkman unique is that it's the first one that I've seen that will actually fit in *my* shirt pocket, yet can still be regarded as a commercially reliable instrument.

Weighing in at just 100 grams and measuring only 4 1/2 x 3 x 1/2 inches in size, the Checkman is a three-function tester; you can measure dc volts, ac volts, and resistance. The dc volt range is from 200 mV to 500 volts, with an accuracy of ±2 percent at 200 mV and 1.3 percent at 500 volts. Its ac volt range is 2 to 500 volts at 2.3 percent accuracy, from 40 to 500 Hz. Resistance can be measured from 200 ohms to 20 megohms, with an accuracy of 2 percent at 200 ohms and 10 percent at 20 megohms.

All ranges are automatically set by the meter. Input impedance is 12 megohms at 2 volts and 11 megohms for other ranges. Operating on the principle of dual slope integration, the meter samples the circuit under test twice per second, indicating its readings on a 3.5-digit LCD readout measuring 10 m high.

In tests run using an analog VTVM and another digital multimeter as a control, the Checkman compared favorably. The margin of difference between the three units was insignificant in each test.

This is a neat little meter. It weighs practically nothing and really *will* fit in your shirt pocket. Technicians will find it easy to carry all day on the job; you'll no doubt appreciate its small size and portability, too.

Covered by a 30-day, money-back guarantee and a full one-year warranty, the Checkman is available from Eaglestone, 84 Research Drive, Milford, CT 06460.

— N1ACH

NEW products

220-MHz HT

Yaesu U.S.A. has introduced the FT-109RH, a 5-watt, 220-MHz handheld transceiver. The FT-109RH joins the popular 2-meter FT-209RH 2 and the 440-MHz FT-709R handhelds.

The FT109RH covers the frequency range of 220 to 224.995 MHz in 5- or 10-kHz steps. All features of previous models are incorporated, including the exclusive Yaesu battery saver, ten memories, standard or non-standard offset, as well as memory and priority scanning. The unit comes equipped with a DTMF tone generator; a front panel multimeter indicating battery condition, transmitter power output, or received signal strength; and a VOX system for hands-free operation. All optional accessories are interchangeable with other units in the FT-109, 209, 709 series, including a VOX headset, speaker/mic, programable tone squelch, dc car adapter, quick/trickle desk charger, and a durable leather case.

For details, contact Yaesu U.S.A. Amateur Products Division, 17210 Edwards Road, Cerritos, California 90701

Circle #303 on Reader Service Card.

new compact speaker

MFJ Enterprises, Inc. has announced the release of its MFJ-280, a high quality compact speaker for only $18.95.

This unit is a rugged, compact mobile speaker with a tilt bracket on a magnetic base. It comes with a 3-1/2-mm phone plug on the end of a long cord and works well with all 8- and 4-ohm impedances and can handle up to 3 watts of audio. Its dark gray color harmonizes with nearly all rigs.

This MFJ product comes with MFJ's double guarantee. If ordered from MFJ, it may be returned within 30 days for a full refund, less shipping. MFJ also backs this product with its one-year unconditional warranty.

For more information, contact MFJ Enterprises, Inc. P.O. Box 494, Mississippi State, MS 39762.

Circle #302 on Reader Service Card.

PCPLOT version 3

BV Engineering has just released version 3 of its PCPLOT high-resolution graphics program. Now PCPLOT not only makes linear and logarithmic plots, but will also plot line graphs with error bars, stock market charts, bar charts, and stacked bar charts. PCPLOT supports two in

dependent Y-axes which can be scaled to different data sets. Data points can be connected with dotted, dashed, or solid lines. Open plots, grid lines, or tick marks may be specified. You can mix line graphs, bar charts, stacked bar charts, stock market charts, and error bars on a single graph. X and Y data may be separately scaled. Legends can be specified on an individual data file basis. Alphanumeric labels can be placed anywhere on the plotting surface. AUTO features enable PCPLOT to take instructions from a file instead of the keyboard.

PCPLOT is compiled in machine code to run quickly. A complete semi-log graph of two data files, each containing 200 data points, takes only 1 minute on a stock IBM PC.

PCPLOT Version 3 sells for $95.00 and runs on the PCDOS and MSDOS operating systems.

For information, contact BV Engineering, 2200 Business Way, Suite 207, Riverside, California 92501.

Circle #306 on Reader Service Card.

new QTH for Kenwood

Because of Kenwood's growth over the last several years, it has become necessary to move into a new, larger facility. The building spans over ten acres in Carson, California and employs 200 in the warehouse and offices.

This move represents the final phase of Kenwood's consolidation process, in which Kenwood Electronics and Trio-Kenwood Communications will be joined by a new division, the Test Equipment Group. Collectively, the communications and test instruments sections will create a new group within the Kenwood Corporation, called the Communications and Test Equipment Group.

The new office is located at 2201 East Dominquez Street, Carson, California 90810.

ultralinear amplifier

WI-COMM Electronics' "Superlam" series now includes the WLA06M Wideband Ultralinear Amplifier, a broadband, feed-forward amplifier covering the frequency range from 0.4 to 80 MHz. This unit employs a field-proven, feed-forward linearization technique to achieve distortion performance equivalent to a 100-watt linear power amplifier. The 3rd order and 2nd order intercept points are typically 62 dBm and 95 dBm, respectively. A linear output power of 1 watt can be delivered into a 50-ohm load with 20 dB of gain. Noise figure is 6 dB and VSWR is better than 1.5:1. Standard powering is 25 ±1 VDC, 600 MA.

The amplifiers are housed in a die-cast blue aluminum case with BNC female connectors. The unit is particularly suitable for signal distribution networks, receiver multicouplers and intermodulation testing.

For more information, contact WI-COMM Electronics Inc., P.O. Box 5174, Massena, New York 13662.

Circle #304 on Reader Service Card.

cable and connector guide

Nemal Electronics International has released its new 1987 Cable and Connector Selection Guide. The 36-page guide includes more than 100 new cable and connector products covering a wide array of rf coaxial, microwave, broadcast, communications, and data applications. Extensive cross-references and illustrations simplify selection of the appropriate cable, connector and tooling for any application. The guide also includes information on the design and production of Nemal's line of Cable Assemblies.

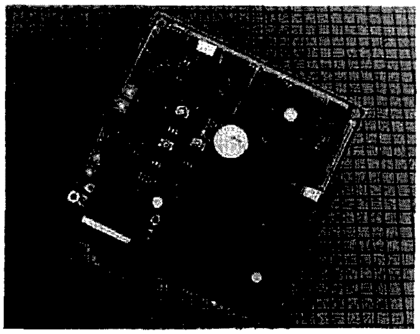
For a copy of the guide, contact Nemal Electronics, Inc., 12240 N.E. 14th Avenue, North Miami, Florida 33161.

Circle #307 on Reader Service Card.

repeater controller

The new S-COM "5K" repeater controller is a low-cost, compact addition to S-COM's line of repeater controllers. The state-of-the-art CMOS microprocessor design supports both a repeater and a control receiver, and requires only 60 mA at 12 Vdc. Applications include control of main site repeaters, remote receiver links, portable repeaters, and emergency repeaters.

Operating parameters such as ID callsigns, courtesy message, timeout timer, pre- and post-timeout messages, CW pitch, and CW speed, are remotely programmable via DTMF commands, eliminating trips to the repeater site for programming changes. Data is retained in non-volatile memory. Three logic inputs and three logic outputs are provided for site control and monitoring purposes.



Among other features are CW shaping, a watchdog monitor, flexible repeater interfacing, a CW clock and calendar, DTMF muting, security passwords, a "polite" identifier, transient protection, power MOSFET outputs, and high-quality G10FR glass epoxy PC board. The board measures 5 1/2 by 6 inches, with the tallest component only 1/2 inch above the board.

Options include full IC socketing, a 1 3/4 x 19-inch rack mount cabinet, a wall-mount power supply, and an audio delay module. The assembled and tested board, with all connectors and manual, is priced at $179.

For information, contact S-COM Industries, P.O. Box 8921, Fort Collins, Colorado 80525.

Circle #308 on Reader Service Card.

NEW products

spring catalog

Heath's colorful new catalog features more than 400 electronic kit products, including a 9-inch diagonal color television, a new security light control, special savings and a Partnership Pack gift offer that's free with every computer purchase.

For a free copy, contact Heath Company, Dept. 150-925, Benton Harbor, Michigan 49022. (In Canada, contact Heath Company, 1020 Islington Avenue, Toronto, Ontario M8Z 5Z3.

Circle #309 on Reader Service Card.

tone output switch module

Communications Specialists, Inc. is now offering a Tone Output Switch Module as an add-on accessory for their TP-38 Shared Repeater Tone Panel. Dubbed the TP-TOS, this new accessory provides individual discrete switch outputs for the standard 32 tone frequencies from 67.0 to 203.5 Hz. The 32 outputs can be configured to provide either a pull to logic ground, a pull to logic high, or to route an audio signal to another transmitter, receiver, tape recorder, etc. The TP-TOS is available on new TP-38's or may be factory-retrofitted into existing units. Priced at $99.95, the TP-TOS is in stock and is covered by a one-year factory warranty. A catalog is available on request.

For details, contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665.

Circle #310 on Reader Service Card.

six-digit jumbo LED clock

Model 1036 has 12- or 24-hour display capability with six 2.25-inch red LED digits. The battery-backed up quartz crystal time base automatically

takes over during power failures. (The clock will also operate from 12 volts dc.) The dimensions are 15.25 x 4.75 x 1.5 inches, providing a viewing distance of over 100 feet.

The model 1036 is available in kit form with step-by-step instructions for $69.95 or assembled and tested for $99.95. (For green LEDS, specify Model 1036G and add $10.00.) For more information, contact NRG Electronics, P.O. Box 24138, Fort Lauderdale, Florida 33307.

Circle #311 on Reader Service Card.

zipper case tool kits

Hand Tool Industries has introduced a full line of tool kits for service, installation and maintenance technicians and engineers servicing electronic equipment. This full line is in addition to the complete selection of attache-type tool kits also offered by Hand Tool Industries.

Many of the kits are engineered for a specific electronic application, such as office machines, or telephone equipment. However, several are designed to handle multi-purpose service needs, such as the HTK-30, which provides the engineer or technician a variety of tools with which to work on copiers, drives, computers, and varied similar type electronic equipment.

Full details on each zipper kit and case, plus all the attached kits and cases, may be obtained by contacting Hand Tool Industries, Inc., Department ZC, 1933 Lake Street, Kent, Ohio 44240.

Circle #312 on Reader Service Card.

automatic modulation meter

CT Systems' new fully automatic Modulation Meter, Model 4101, was designed to simplify am and fm modulation testing. Already in use in both field environments and manufacturing facilities, its simple pushbutton switches allow for front-panel selection of function, meter range, filter and de-emphasis.

Automatic measurements can be made from 1.5 MHz to 2.0 GHz of fm deviation to 100 kHz and a-m modulation to 100 percent. Input levels from 3 mv to 1 v, selectable de-emphasis of 50, 75, or 750 μseconds. Both i-f and a-f outputs are standard.

Priced at $1395, the 4101 Modulation Meter has a large easy-to-read meter, three selectable filters and is available with a rechargeable battery option. For information, contact CT Systems, Inc., 5245 Hornet Avenue, Beech Grove, Indiana 46107-0470.

Circle #313 on Reader Service Card.

Model 12 CW processor

Much more than just a good filter, Don Hildreth's Model 12 CW processor provides a synergistic sequence including a 4th-order Butterworth offset first filter, a selectable prelimiter, an 8th-order Butterworth cascade linear filter, a two-stage carrier-activated limiter system and a power amplifier.

Selection of these elements can provide S/N enhancement and impulse noise suppression (much beyond a simple limiter), and ringing suppression. It can even handle multiple woodpecker interference and short-duration atmospherics. Output power is up to 2 watts of audio into a 4- to 8-ohm speaker.

The input requirement to the unit is from +13 to +15 volts dc at a nominal 0.3 amps. Operation may be obtained with +12 volts, but with reduced audio power. Input impedance is 2.2 k resistive, to allow driving the unit from either a receiver's speaker or headset port. The maximum required signal level for normal operation is 0.5 volts peak-to-peak at 750 Hz.

This device (and its technical rationale) was decribed in two *ham radio* articles: "Carrier-Activated CW Reception Limiter" (September, 1985) and "Advanced CW Processor" (December, 1986). For further details, contact Hildreth Engineering Corporation, P.O. Box 60003, Sunnyvale, California 94088.

Circle #314 on Reader Service Card.

hf base station transceiver

Incorporating advanced new features, the ICOM IC-761 measures approximately 17 x 6 x 15 inches, and is conservatively rated at 100 watts output on CW, SSB, FSK, and SSTV. The transmitters's 28-volt power amplifier uses two husky 2SC2904's operating in push-pull. An internal whisper-quiet cooling fan and large heat sink are included for continuous 100-percent duty cycle operation.

The IC-761 also includes a built-in switching-type ac power supply plus a built-in automatic antenna tuner. The tuner is capable of matching a wide range of impedances from 16 to 150 ohms.

The IC-761's receiver continuously tunes from 100 kHz through 30 MHz, with sensitivity exceeding 0.15 microvolts. The receiver is a triple-conversion, superheterodyne, featuring a low noise, direct-feed mixer circuit. Its dynamic range is 105 dB, with a selectable AGC action.

Receiver performance is further enhanced with passband tuning, i-f shift, i-f notch, and a dual-width adjustable-level noise blanker. Frequencies may be selected via the main tuning knob or entered from the front keypad or from a computer with the ICOM "CI-V" interface kit. Thirty-two memory channels are available with direct memory channel input to VFO "A" or "B" for semi-duplex or split-band operation.

Special CW features include a built-in electronic keyer and a steep-skirted narrow CW filter. CW and RTTY selectivity is 500 Hz at 6 dB and 1,000 Hz at 60 dB. The audio notch null is greater than 45 dB. Semi and full break-in keying is rated to 60 WPM.

The IC-761 carries a one-year warranty from the date of purchase, with factory support from four regional service centers located in Atlanta, Georgia; Bellevue, Washington; Irving, Texas; and Vancouver, British Columbia.

For further information, contact ICOM America, Inc., 2380 116 Avenue N.E., P.O. Box C-90029, Bellevue, Washington 98009-9029.

Circle #315 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance.** No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (not all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc. are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.

ILLINOIS: July 12. The DuPage Amateur Radio Club is sponsoring a Hamfest/Computershow, American Legion Post 80, 4000 Saratoga, Downers Grove. Outdoor flea market and swappers row. Indoor tables available. General admission $3.00/gate; $2.00/advance. Gates open 8 AM. Free parking. Food and drink available. Talk in on 146.52 simplex and 145.250-600. For tickets or reserved tables SASE to Hamfest Chairmen, W9DUP, POB 71, Clarendon Hills, IL 60514 or call (312) 985*0527 evenings or weekends.

TENNESSEE: August 2. The Maury ARC will sponsor its first annual indoor Hamfest, American Legion Post 19, New Nashville Highway, Clumbia. 8 AM to 4 PM. Admission $2. Tables $5. Food/refreshments. VE license exams. Talk in on 147.72/.12. For information or reserved tables: George Russell, WB4JCR, Box 832, Columbia, TN 38402 (615) 388-0577.

VIRGINIA: August 2. The 37th annual Winchester Hamfest, sponsored by the Shenandoah Valley ARC, Clarke County Ruritan Fairgrounds, Rt. 7, Berryville. 7 AM to 3 PM. Admission $4. VE exams 9 AM. Limited walk-ins. Talk in on 146.22/.82 and 52. For information Rob Kinsley, NT4S, SVARC, POB 139, Winchester, VA 22601. (703) 869-5113.

PENNSYLVANIA: August 2. The 50th GOLDEN Hamfest of the South Hills Brass Pounders Nd Modulators ARC, South Campus of Community College of Allegheny County, West Mifflin. Indoor/outdoor flea market. Talk in on 146.13/73 and 146.52 simplex. For more information: Doug Wilson, WA3ZNP, 185 Orchard Avenue, Emsworth, PA 15202.

WISCONSIN: July 11. The Eau Claire ARC will hold its annual Hamfest, 4-H buildings on Fairfax Street, Eau Claire. 8 AM to 2 PM. Tickets $2/advance; $3/door. Free tables and coffee. Talk in on 147.84/.24. For information/tickets SASE to Gene Lieberg, KA9DWH, 2840 Saturn Avenue, Eau Claire, WI 54703.

TEXAS: August 7-9. Austin Summerfest. Sponsored by the Austin ARC and Austin Repeater Organization. Villa Capri Motor Hotel, 2400North Interstate 35, near center of Austin. Flea market, dealers, ARRL forum, tech programs, transmitter hunt. Saturday barbeque and Midnight Wouff Hong ceremony. Advance fees $5 for general registration; $7 at the door. Children 15 and under free. $9 for advance barbeque tickets. $5 for each swap table. For registration/information write Austin Summerfest, PO Box 13473, Austin, TX 78711.

NEW JERSEY: July 19. The Sussex County ARC will sponsor SCARC '87, Sussex County Fairgrounds, Plains Road off Rt 206. Doors open 8 AM. Registration $3.00. Indoor tables $7.00 each. Tailgating $5.00/space. Food and refreshments. Free parking. Write: Don Stickle, K2OX, Weldon Rd, RD 4, Lake Hopatcong, NJ 07849. (201) 663-0677.

OKLAHOMA: July 31-August 2. Central Oklahoma Radio Amateurs (CORA) Ham Holiday and State ARRL Convention, Lincoln Plaza, 4445 North Lincoln Blvd, Oklahoma City. Hi-tech programs and demonstrations. VE tests, ARRL forums as well as non-technical programs. Saturday and Sunday flea market. Saturday night banquet. Sunday morning WCWA breakfast. Pre-registration (by July 22) $7.00. Flea market tables $2.00 with pre-registration. Registration $9.00/door. Talk in on 147.63/147.03. For details write CORA Ham Holiday, POB 850142, Yukon, OK 73085-0142.

OREGON: July 25 and 26. The Willamette Valley DX Club of Portland will host the annual Northwest DX Convention, Greenwood Inn, Beaverton. For information write Willamette Valley DX Club, 58731 Columbia River Highway, St. Helens, OR 97051.

BRITISH COLUMBIA: July 11 and 12. Maple Ridge Hamfest, St. Patrick's Center, 22589 121 Avenue, Maple Ridge. Admission: Hams $6.00; Non-hams over 12 $3.00. Under 12 free. Two hams, same family $9.00. Flea market, commercial displays, nearby shopping. Camper space, no hookups. Talk in on 146.20/80, 146.34/94. For information: Floyd Beardsell, VE7HI, Box 292, Maple Ridge, BC V2X 7G2.

NEW YORK: July 11. The Mt. Beacon ARC's Hamfest, Arlington Senior High School, Poughkeepsie/Lagrange. Tickets $3.00. Tailgating $4.00/space. Doors open 8 AM. Talk in on 146.37/97 and 146.52. For information Julius Jones, W2IHY, RR2, Vanessa Lane, Staatsburg, NY 12580. (914) 889-4933.

MISSOURI: July 19. The 25th annual ZERO-BEATERS Hamfest, Bernie Hillerman Park (Washington, MO Fairgrounds). 8 AM to 3 PM. Free admission – free parking. FCC exams, Flea Market Space $2.00/car. Food and refreshments available. For information Zero-Beaters ARC, Box 24, Dutzow, MO 63342. (314) 239-2072.

MONTANA: July 17-19. The Great Falls Area ARC will sponsor the 53rd annual Glacier-Waterton International Hamfest, Three Forks Campground, southern edge of Glacier National Park. Seminars, contests, QCWA meeting and more. Talk in on 10/70 and 52. For more information: Shirley Smith, KC7OA, 1822 14th Avenue South, Great Falls, MT 59405. (406) 452-5958.

WISCONSIN: July 18. The South Milwaukee ARC will hold its annual SWAPFEST, American Legion Post 434, 9327 South Shepard Avenue, Oak Creek. 7 AM to 3 PM. Admission $3.00. VE exams, picnicking, refreshments. Free overnight camping on grounds. Talk in on 146.94. For details: The South Milwaukee ARC, POB 102, South Milwaukee, WI 53172-0102.

MASSACHUSETTS: July 24, 25, 26. The 2nd ARRL "Heavy Hitters Hamfest", Topsfield Fairgrounds, US Rt 1, Topsfield. Indoor/outdoor flea market, Contests, fox hunts, packet radio and RTTY mailbox demos. License exams, alternative activities and more. Free camping Friday and Saturday nights for tents and SC RV's. Nearby hotels. Advance tickets $3.00. $4.00/door. Children with adults admitted free. For more information Russ Corkum, WA1TTV, 21 Thorndike Street, Arlington, MA 02174.

NORTHWEST USA: July 31, August 1 and 2. The 55th annual Wyoming, Idaho, Montana, Utah Hamfest, Virginian Lodge, Jackson Hole, Wyoming. Friday evening Cowboy Cookout, seminars, forums, speakers and Sunday Awards presentation. Non-ham activities. Nearby shopping. And Grand Teton and Yellowstone National Parks. QCWA Hospitality Suite. Free swap tables. Tickets $10/door or $8/advance by July 20. RV parking next door at A-1 Campground. For registration/ information contact: WIMU87 Hamfest, c/o Cheryl Ransom, KA7QOE, HC36-205, Riverton, WY 82501. (307) 856-1811.

PENNSYLVANIA: August 9. The Mid-Atlantic ARC announces its annual Hamfest, Bucks County Drive-in Theater, Rt 611, Warrington. 8 AM to 3 PM rain or shine. Admission $3.00. Tailgating $2.00 extra. Setups 7 AM. Bring own table. Talk in on WB3JOE/R, 147.66/.06 or 146.52. For information write MARC, 203 Second Avenue, Broomall, PA 19008 or call John Bartholomew, WB3ELA (215) 356-7197.

ILLINOIS: August 9. Hamfesters Radio Club, celebrating its 54th year of Amateur Radio service, is having its 53rd annual Hamfest, Santa Fe Park, 91st and Wolf Road, Willow Springs (near Chicago). Donation $3/advance; $4/door. For information call: (313)403-1043.

INDIANA: July 11 and 12. The 17th annual State ARRL Convention and Hamfest, Marion County Fairgrounds, Indianapolis. Gates open 6 AM both days. Gate fee $5. Children under 12 free. Food available on grounds. Nearby motels and restaurants. Flea market, dealer displays, tech forums. Camping on grounds with free hookups provided by Hamfest Assn. For info on flea market space: (317) 356-4451. For info on commercial space: (317) 745-6389.

WISCONSIN: July 18. The South Milwaukee ARC will hold its annual Swapfest, American Legion Post 434, 9327 South Shepard Avenue, Oak Creek. 7 AM to 3 PM. Parking, picnicking, food, refreshments and free overnight camping available on grounds. Admission $3.00 includes "happy time" with free beverages. License exams. Packet meeting. For details write South Milwaukee ARC, PO Box 102, South Milwaukee, WI 53172-0102.

WEST VIRGINIA: July 19. The 9th annual TSRAC Wheeling Hamfest/Computer Fair, Wheeling Park. 9 AM to 4 PM. WV's largest. Dealers welcome 30,000 square feet under roof; 5 acres flea market. Family activities at Park. Admission $3.00 in advance; $4.00 at door. To reserve space contact: Carl Williams, WD8PPS, 9 East High St, Flushing, OH 43977. For tickets: TSRAC, Box 240, RD 1, Adena, OH 43901 (614) 546-3930.

WASHINGTON: August 22-23. The Radio Club of Tacoma presents Hamfair '87 and the ARRL Northwestern Division Convention, Pacific Lutheran University, Tacoma. Friday evening entertainment. Doors open 9 AM August 22. Registration $5.00 til August 12. $6.00 at the door. Banquet $10.00 by August 12. RV spaces $2.00. No hookups. Technical seminars, forums, flea market (tables $18/6') non-ham activities, VE exams all classes. For reservations and/or flea market tables write Al Wittich, KA7SBJ, 3832 Gay Rd E, Tacoma, WA 98443 or call Bill Morgan, W7GRP (206) 531-3821 or Marion O'Neal, WB7SQU (206) 838-3126.

INDIANA: August 9. The 8th annual Grant County ARC Hamfest, 4-H Fairgrounds, Marion. Doors open 8 AM. Refreshments, free parking, VE exams and more. Donation $3.00/advance. $4.00/gate. Inside tables $4.00. Flea market space $2.00. For information or tickets SASE to WB9EAP, Brooks Clark, 2202 South Boots Street, Marion, IN 46953.

NEW YORK: July 12. Genesee Radio Amateurs annual Batavia Hamfest, Alexander Firemen's Grounds, Rt 98, Alexander. 6 AM to 5 PM. Admission $3 advance, $4 at door. Breakfast, flea market, programs, chicken BBQ, VEC exams, free camping. Talk in on 146.52 and 144.71/145.31. For information write GRAM, POB 572, Batavia, NY 14020 or call Dave Harms, KC2RF (716) 342-6770.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.

OPERATING EVENTS

"Things to do . . ."

July 12: Eric NF0Q and Allan KA8JJN will operate NF0Q/8 at Mt. Clemens, MI from 1200Z to 2100Z to commemorate the 200th Anniversary of the Northwest Ordinance of 1787. Primary freqs 7250 and 14325. Secondary 21350, 28410 and Detroit area 2 meter repeaters. For certificates send large SASE to Erick Koch, NF0Q, 2805 Westminister, St. Charles, MO 63301.

July 5-12: The Stateline ARC will operate station KT5I to celebrate the 1987 National Soaring Championships from the new National Headquarters of the National Soaring Society, Hobbs, NM. 10-80 meters. For certificate send QSL and contact number to State Line ARC, KT5I, POB 1423, Hobbs, NM 88240.

July 14: The Valley ARA will sponsor a special events station at the Statler Brothers' "Happy Birthday USA Celebration" in Staunton, VA. 8 AM to 8:30 PM, 14250, 3850 and 7230. For special certificate SASE to N4ICT, POB 1091, Staunton, VA 24401.

July 18-19: The Bolingbrook Amateur Radio Society in conjunction with the City of Naperville, Illinois, will be operating a Special Event Station, KE9DE, to commemorate the Revolutionary Wa. 1400Z to 2100Z. 14.300, 7.250. For certificate send QSL card and No. 10 SASE to Special Event Chairman, Rich Wayne, KE9DE, POB 495, Naperville, IL 60566-0495.

July 7-9: Aboard USS MISSOURI (BB-63). The Naval Postgraduate School ARC (K6LY) will operate a special event station during Fleet Week Monterey in conjunction with celebration commemorating the Gret White Fleet journey of 1907-09. 1700Z-0100Z. Lower 50 kHz of 20 and 15 meters and Novice portion of 10m. For a commemorative QSL card send your QSL card and SASE to NK6H, 96 Cuesta Vista Drive, Monterey, CA 93940.

July 25-26: The Eastern Michigan ARC will operate K8EPV to commemorate the 62nd Port Huron to Mackinac Island Yacht Race. 1400Z to 020Z each day. For large certificate SASE with QSL to K8EPV, 654 Georgia, Marysville, MI 48040.

July 11-12: The Holmdel ARC will operate K2DR to commemorate the 25th anniversary of the launching of the TELSTAR communications satellite. 1500Z to 2200Z July 11 and 1500Z to 2000Z July 12. 20, 40, 80m General phone bands. Lower 25 kHz of Novice 10m phone band. For certificate send QSL and SASE to Holmdel ARC, POB 205, Holmdel, NJ 07733.

July 12: The Buzzard's Roost Repeater Club will operate KC0DA from downtown Petersburg, Nebraska to help this community celebrate its centennial. QSL with SASE to KC0DA, Larry Lehmann, 706 West Fairview Avenue, Albion, NE 68620.

July 26: East Aurora "Racing Day" special event station W2QFC operated by the Pioneer Radio Operators Society (PROS) from the Village Park, once the trotting horse mecca of the world. 10 AM to 5 PM EDST. 3935, 7235, 14235. For a special qSL SASE to W2QFC 308 Parkdale Avenue, East Aurora, NY 14052.

short circuit

real coax

Two errors appeared in Forrest Gehrke's article, "Real Coax" (April, 1987, page 8). In the lower left-hand column of page 12, dB = 0.1151 neper = $\log_\epsilon$ should be corrected to read as follows:

$$0.1151\left(\begin{matrix}Value\\ in\ dB\end{matrix}\right) = \left(\begin{matrix}Value\\ in\ nepers\end{matrix}\right)$$

$$= \log_\epsilon\sqrt{P1/P2}$$

or, if you wish,

$$.1151\ dB = nepers = \log_\epsilon\sqrt{P1/P2}$$

At the top of the right-hand column,

$$10^{dB/10} = \sqrt{P1/P2}$$

should be corrected to read:

$$10^{dB/10} = P1/P2$$

ELMER'S NOTEBOOK

Tom McMullen, W1SL

an introduction to digital communications

I'll explore some of the hows and whys of digital communications in this month's column. But first, I'd like to report on a wonderful Elmer whose work was just called to my attention: Glenn Shaw, W6NI, of Rockport, Texas.

It seems that Glenn has made it a personal goal to be the first contact for new Amateurs. He's been at this for 20 years or so, and has made a lot of friends along the way. Just think how much easier your first contact would have been if you'd known that the guy at the other end of the path was patient and understanding — and wasn't going to laugh at your faltering attempts at sending call letters, QTH, signal reports, name, and all that stuff that's so hard to do on your first contact!

Several of Glenn's "firsts" have gone on to earn Extra class licenses. Many keep in touch by letter or by radio. Glenn has even developed a special certificate to grace the wall of their shacks.

Great work, Glenn, and may your tribe increase! (And thanks to KA5BWL for calling Glenn to my attention.)

the digital business

Now, on to this digital business. It will be many, many license-renewal periods before this mode begins to seriously crowd the bands, but it's an important part of the communications world, and it will become even more important and widespread than it is now. So, don't throw away that key or microphone just yet, but make room for a keyboard alongside.

We've come to think of digital as being associated with computers, but that's not all there is to it. Radioteletype (RTTY) has been around — and on the Amateur bands — for ages. Audio-frequency-shift keying (AFSK) was used on the 11-meter band (when it was still an Amateur band) in early days of RTTY, and is still widely used on VHF and UHF. After 1953, when the FCC allowed FSK to be used on the Amateur hf bands, the *number* of RTTY stations that could be heard "RYing"* on the air increased monthly. *That* was digital communications, even though most Amateurs didn't think of it as such. It was — and is — information propagated by means of pulses, and the pulses were derived from mechanical contacts in a mechanism activated by a keyboard or by contacts that "read" the holes in a punched paper tape.

Pulses have two levels, or states, to their waveform: *high* and *low*. Several conventions are used to describe these states: for example, *on and off*, *1 and 0*, *plus and minus*, *mark and space*, and so forth. It's basically a matter of changing the dc voltage level from one resting value to another, and the change from one to the other is rather abrupt. Individually, these pulses don't do much for us — but groups of them can be put together in a well-defined arrangement, or code, to convey information. American RTTY employs a code called Baudot (which rhymes with "doe"); the British use an almost identical arrangement they call the Murray code. The RTTY system uses five pulses (called "bits") in various sequences that allow transmission of all the letters of the alphabet, numbers, some special functions such as ringing a bell, sending a carriage return and/or a line feed to the receiving system, and others, for a total of 64 characters.

A more modern type of code is called ASCII (from American Standard Code for Information Interchange, pronounced "askey"). This code has seven pulses, with the option of adding another for error-checking purposes (this eighth bit, or pulse, is called a "parity" bit). This allows a code table that includes all the letters, numbers, functions, and symbols you'll ever need, and some you probably won't. A sample of the pulse combinations for the letter Y is shown in **fig. 1**. ASCII tables abound in computer books, handbooks, and textbooks about data processing, so there's no need for me to repeat one here. However, when you do look at an ASCII table, note that it reads backwards compared with the drawing in **fig. 1**. Most tables list the bits in order of significance, with the most-significant bit at the left, as at the beginning of a word. **Figure 1** shows the sequence as it would be transmitted, with the least-significant bit (B0) first. If you have trouble with the notion of significance, look at the dollar amount of $10,005; certainly the "1" is much more significant than the "5" — right? The drawing also shows what happens when two bits of the same polarity (1 or 0) occur together. The voltage doesn't return to its other state between pulses, but stays at the 1 or 0 value for a time duration equal to two bit lengths. **Figure 1** shows two zeros together and two ones together;

*An early test signal, sent *ad infinitum* to let people know you'd mastered the intricacies of getting a system up and running.

**However, the *suppressed* carrier remains at the same frequency. — Ed.

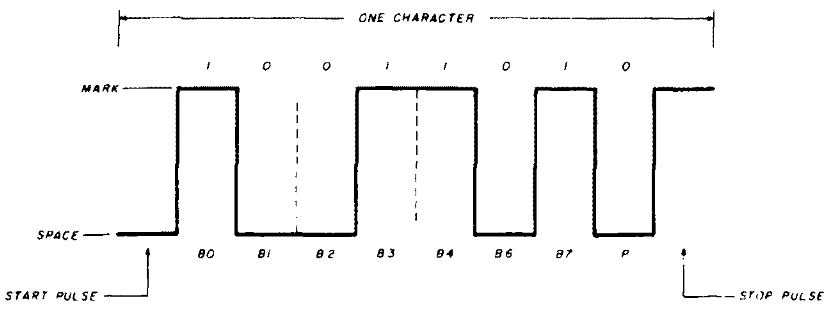


fig. 1. Digital communications take place by means of pulses arranged to represent characters. This is the ASCII code for the letter Y. A start pulse informs the receiver that data bits follow. P is a parity bit, used to check for errors.

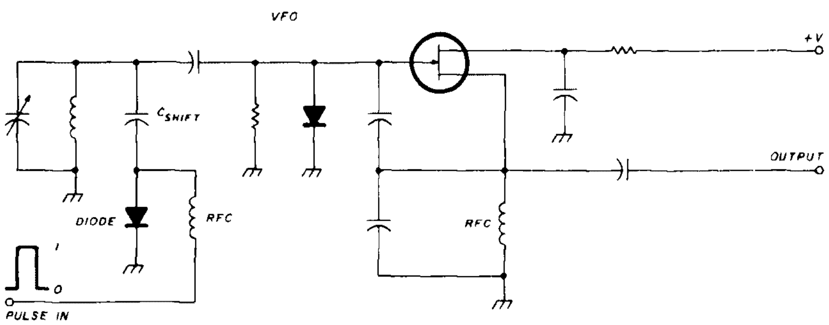


fig. 2. Frequency-shift keying of an rf carrier can be done by switching an extra capacitor in and out of an oscillator circuit. In this simplified circuit, a "high" dc level (pulse at its "1" state,) will cause the diode to conduct, placing C_S in the circuit, thus lowering the frequency. See text for another method of generating FSK.

the dotted line merely illustrates that there are two bits there.

the bit connection

All this business about pulses and bits and ones and zeros is fine, but how do you apply them to a transceiver? Can you just hook the output of a keyboard to the microphone jack and start cranking out digital stuff? Well, no — not unless you have a very unusual transceiver. You'd get an awful lot of clicks from the fast transitions from 0 to 1 and back (plus an equal number of irate phone calls from your neighboring hams whose QSOs you were messing up).

Two basic methods of transmitting digital information are in use on the Amateur bands today: frequency-shift keying (FSK) and audio-frequency-shift keying (AFSK).

FSK, as used on the hf bands, can be generated by either of two methods. One way is to change the frequency of an oscillator in response to a pulse, with a circuit such as the one shown in **fig. 2**. In this simplified diagram, a diode is in series with an extra capacitor across an oscillator coil. When the dc level at the anode end of the diode is at 1, the diode conducts, and the capacitor is "in," causing the frequency to be at its lowest value. When the pulse falls below the diode's conduction level (the pulse is at its "0" state), the capacitor is "out," and the oscillator frequency is higher. The difference between the two frequencies is called "shift," and is usually 170 Hz in most applications. With proper design and careful attention to temperature compensation and mechanical stability, this is a very satisfactory system. For years direct FSK was the only system on the hf bands.

The increased availability of SSB equipment, and the frequency stability of these rigs, has brought forth another method of creating FSK for the digital modes. When you apply a pure sine wave to an SSB modulator, you generate a single-frequency rf carrier (that's how you tune up your SSB rig, isn't it?). Now, if you cause the audio frequency (sine wave) to change by the desired shift, the generated** rf carrier frequency is going to change right along with it, with the result that someone listening won't be able to tell the difference between this method and that described in the preceding paragraph: both produce a shift in the rf carrier frequency in response to the state of the modulating pulse.

The audio frequency can be made to shift by several methods: by using diodes or transistors to switch coil or capacitor values in and out of an oscillator circit; by switching separate oscillator circuits in and out; or by using a microprocessor to synthesize the audio frequencies needed.

So, it all comes down to this: the "encoding" device — which can be a keyboard, a set of contacts in a mechanical arrangement, or a computer — must be hooked to either an hf transmitter (or transceiver) by means of a diode frequency-shift circuit or to the microphone input of an SSB rig when audio-frequency-shift is used to generate the carrier. For VHF and UHF fm equipment, straight AFSK is used, and audio tones can be applied directly to the microphone input (or sometimes to an auxiliary input circuit that doesn't need the high gain provided by most microphone circuits).

Most equipment used today includes some form of built-in modulator that translates the strictly dc, on/off pulses into something that a transmitter can work with. You might

even find it combined with a demodulator and called a *modem* (modulator-demodulator). Whatever it's called, it's connected between the keyboard and the transmitter.

Modern digital equipment available for Amateur use is designed to connect easily to most common transmitters or transceivers, and the manufacturer's instructions make it relatively simple to get a station on the air. However, it's best to read carefully and ask questions to be sure that the pieces can get along with each other (in high-tech language, this is called "compatibility").

other modes

Packet Radio — the fastest growing aspect of Amateur Radio today — is a special application of digital codes. There's also a system called AMTOR that really helps overcome errors caused by noise and fading. I'll cover these in one or more future issues. They're both fascinating modes of communication, and once you understand what they can do and why, you'll enjoy untold hours of enjoyable operation. (If you enjoy "alphabet soup" such as RTTY, ASCII, SSB, and others you've seen in this column, wait 'till you get to Packet — with its DCEs, DTEs, layers, protocols, RS-232, CCITs, etc. You'll love it!)

10-meter prospects

While we're looking at the digital part of the new privileges, let's not forget the rf side of it all. Although the 10-meter band seems like never-never land at the moment, don't cross it off too quickly. There have been a few openings recently (March and April) where the other side of the world was booming in with "ham-in-the-next-block" signal strength, and some of the signals stayed for hours. As sunspot activity increases gradually over the next three to four years, propagation on 10 meters can only get better. Now's the time to get your new station assembled, tested, fine tuned, and ready for the wall-to-wall DX that 10 meters offers in its better moods. This is a great time to try new skills and modes, when the band is usually dead for DX but provides superb interference-free local communications. So, all you Elmers out there, set up some skeds with your favorite Novices or Techs and help them practice the new techniques; when the world is accessible on 10 meters, they'll be ready to communicate. Meanwhile, if there happens to be a great opening to Europe, Africa, New Zealand, Australia, or the Philippines, they'll be there to enjoy it.

For a more thorough — yet still basic — discussion of digital communications, see *The Digital Novice* by Jim Grubbs, K9EI. Available from Ham Radio's Bookstore, Greenville, NH 03048 for $9.95 plus $3.50 shipping and handling. — Ed.

ham radio

229

AUGUST 1987 / $2.50

ham radio
magazine

hr

focus
on
communications
technology

ham radio magazine

AUGUST 1987

volume 20, number 8

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Canada and other countries (via surface mail):
one year, $31.00; two years, $55.00; three years, $74.00

All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

international subscription agents: page 89

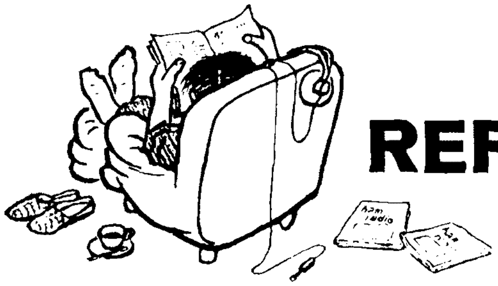
Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio* are available to the blind and physically handicapped from Recorded Periodicals, 919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents



REFLECTIONS

evolution

In September, 1983, we published a survey soliciting your opinion on a number of subjects. In that survey, we asked about your use of computers, including any that you owned or had access to. In your responses, 50 percent of you answered affirmatively. Many of you — even those who were "computerized" — indicated clearly that you did not wish to see *ham radio* turn into yet another "computer book."

Since that time, however, the complexion of Radio Amateurs has changed. What used to be packet freckles can now be likened to a full tan after basking in the warmth of this useful and entertaining mode of communication. Most who predicted the yearly growth rate of this digital phenomenon were wrong, erring on the low side. *ham radio*, for its part, published articles that emphasized some of the more technical aspects of packet radio, such as TEXNET's recent three-part series on packet networking (March, April, and June, 1987).

Concurrently, even though statistics indicated a higher median and mean age of Radio Amateurs, some of the faces started to look younger, with Novice Enhancement bringing in a welcome influx of youth.

One concern raised by many readers responding to the survey brings new wrinkles to the face of Amateur Radio; many voiced and continue to voice the opinion that no one's building any more. Does anybody build any more? Well, it depends on how you define building. Yes, it's true that far fewer of us design and build our own receivers and transmitters nowadays, but this is quite understandable in light of the abundance of high performance and versatile commercial units available. With few exceptions, there's simply no need to build equipment today; without running a cost analysis, I'd almost be willing to bet that on a percentage basis the cost of a present-day rig eats up less of your earned income than a state-of-the-art rig would have consumed 10, 20, or 30 years ago.

From what I see in the manuscripts that arrive here, it appears that there's been a redirection or refocusing of attention to the more sophisticated technologies and techniques. A trend seen years ago in the Aerospace industries — a "systems" approach to construction — is now evident in Amateur projects. Recognizing that "soup-to-nuts" designs were no longer cost-effective, aerospace industries turned to modular construction, letting those individuals or companies who could build a better mixer, for example, supply that component. This same trend, I believe, has permeated Amateur Radio; it's just not cost-effective to build a 2-meter station when, for a few hundred dollars, you can buy a multi-function miniaturized unit. Personally, I'll still repair them . . . but try to compete on a design/construction basis? No way! I don't know how you value your time, but I can assure you that the price tag I'd put on a similar unit that I'd built would have to be a lot higher than the one you'd find on any off-the-shelf unit.

There's an inherent danger lurking in this path of reasoning, however: we don't want to become jacks of all trades and masters of none. I reconcile this dilemma by reading more, zeroing in on several specific areas of technical interest, and using computers more than ever before. Sometimes I just have to sit back and laugh at the amount of time I spent preparing a 24-hour propagation forecast by hand for just one point-to-point path a few years ago. It took hours. This process is now reduced to seconds with affordable computers . . . which is my next point: we're still constructors — *but* what we're "building," in many cases, are computer routines instead of hardware. I don't think it's fair to say which is more related to Amateur Radio. Like everything else, Amateur Radio is evolving through a logical sequence of events.

All I ask of you is to provide me with a glimpse of your new interests, regardless of the form (i.e., hardware or computer programs) they take. Let us help in the evolutionary process by sharpening the focus and providing a few more details.

Rich Rosen, K2RR
Editor-in-Chief

comments

improving writing skills

Dear HR:

I'm writing this letter in response to conversations I had at the recent Dayton Hamvention™ with you [Rich Rosen, K2RR], Bob Grove (editor of *Monitoring Times*), and several others of us who write for radio communications journals. There was considerable interest expressed by these persons in the possibility of organizing a meeting at next year's Hamvention that would be oriented toward those who write — or would like to write — for radio communications journals.

The program could present several speakers who would cover various areas of interest. The first speaker, probably an editor from one of our popular journals, could address the question of what beginning writers need to know in order to begin writing for the journals. Another speaker, or perhaps better yet, a panel of speakers, could offer ideas for already-published writers who want to improve their skills. Thirdly, a well-known, successful writer such as Joe Carr, K4IPV, Ed Noll, W3FQJ, or Bill Orr, W6SAI, might offer words of wisdom to aspiring writers who want to move up the ladder of professionalism in writing on the subject of radio technology.

As far as I know, there is no organized way for radio communications writers to contact one another, exchange information, or share ideas. In addition to being useful in its own right, the meeting proposed above might present a good opportunity for the founding of a writer's group or writer's newsletter for those of us who write for radio communications journals.

I hope that writers — both published and potential — who are interested in any of these ideas will contact me with lists of the kind of information they'd like to see covered in such a program, and which writers and editors they would like to hear speak. If the feedback is sufficiently positive, perhaps I could approach the appropriate committee to see if such a program could actually be arranged for next year's Hamvention.

W. Clem Small, KR6A
Salisbury, Vermont 05769

grounding, shielding

Dear HR:

I enjoyed reading K4IPV's column, "Practically Speaking: Grounding, Shielding, and Isolating — Part 2," in the May issue of *ham radio*. However, I felt a few comments might be in order.

First, I think that readers would be more satisfied with the performance of one-inch, or even half-inch, copper strap in place of the suggested braid. Braid becomes increasingly inductive faster than strap or even heavy wire at the TVI frequencies the author is concerned with.

Second, I would strongly suggest that if brazing is inconvenient, silver solder should be used for all soldering that may be exposed to the elements. Regular solder seems to "decompose" when exposed to weather, leaving a joint that is electrically and often visually similar to a cold solder joint.

I hope these suggestions will improve someone's hamshack.

Gary D. Sharpe, KA8DKT
Beaumont, Pennsylvania 18618

continuous phase tones

Dear HR:

Richard Ferranti's article, "Amateur FSK: A Spectral Analysis" (December, 1986, page 42) clearly makes the case for continuous phase tones for radio modems. This theme is even more pertinent if we directly modulate coherently the radio frequency carrier instead of using tones.

Modems were evolved for cables and telephone lines in order to make data look like a sound spectrum. Their purpose was to overcome the inductance and capacitance of cables, and though the same technique will work on a radio channel, we have a much more linear system with a wider useful bandwidth.

I feel we should be using our data signals to shift the radio frequency carrier directly — i.e. without the use of audio tones.

Had the author extended his discussion from fm to SSB, he would have found that an on-the-air signal would be more or less two separate frequencies separated by the difference in the tones and the advantages of phase coherence would be very marked. However, the SSB method is complex and wasteful of power, and to apply the data in the generation of the carrier is simpler and cheaper. All that's required is to switch a small capacitor across the crystal — but beware of the effect of the synthesizer, which may turn the square waves into triangular ones.

Another way of generating coherent phase fm is to impress the data as ripple on the supply to a free-running oscillator. Work is going on along these lines for a radio link between computers and peripherals in an effort to overcome interference and security problems.

R.J. Redding, G3VMR
Maidenhead, Berks, SL63EL

modifying the MLA-2500 amp

Dear HR:

A lot of us still have Dentron MLA-2500 amps, which use the Eimac 8875s. You know what they cost to replace.

How about an article on modifying this amp to use less expensive tubes? I've had mine since 1978, and it's still OK, but when the 8875s go, I doubt if it will be worth $700 or so for new ones.

Thanks for your fine magazine and keep up the good workl

Joe W. Williamson, KB5YA
Killeen, Texas 76541

Ideas, anybody? — Ed.

solar activity
and the earth's magnetosphere

A close look at the energy source responsible for worldwide communications

Although Amateurs have been aware of a relationship between solar activity and ionospheric conditions since the earliest days of radio, concentrated studies in these areas did not begin until after the end of World War II. While many questions remain unanswered, we now have a large body of knowledge about solar activity and its effects on the Earth's magnetosphere, the region of charged trapped particles above the Earth controlled by our magnetic field. This information allows us to predict, with some degree of certainty, ionospheric activity and its effects on the parameters of hf radio propagation.

Such knowledge can provide some measure of solace to the intrepid DXer who, with an hour to spare from family obligations, has discovered that a Sudden Ionospheric Disturbance is in progress or that Polar Cap Absorption has wiped out the short path to Europe. These disruptions are the result of changes within the ionosphere, brought about by earlier flares and eruptive prominences on the surface of the Sun; this activity, in turn, results from still earlier processes originating deep within the Sun's interior.

historical perspective

Our understanding of solar activity began when physicists calculated and tried to explain the enormous output of energy from the Sun. In 1871, Hermann von Helmholtz calculated its energy production as the equivalent of burning 1500 pounds of coal per hour on each square foot of the solar surface. Since ordinary chemical reactions cannot produce these energy levels, scientists realized that solar energy could not be explained in terms of conventional chemistry.

Some years later, Lord Kelvin proposed a solution to the problem, suggesting that solar energy could be attributed to the energy released from gravitational contraction; even if the solar surface contracted by 100 feet per year, the Sun could shine for 30 million years. However, geologists soon produced evidence that the Earth had existed for much longer than 30 million years, and astronomers were then compelled to devise new theories of solar energy.

nuclear energy

In the 1920s, scientists realized that nuclear reactions could provide the necessary vehicle for energy production. Chemical reactions involve interactions only between the electron structures of various atoms. Nuclear reactions — whether by fission or fusion — involve the release of energy through the restructuring of an atom's nucleus. Nuclear fusion reactions, they found, do two things within a star: they provide a tremendous amount of energy and, over long periods of time, change its composition. In a dwarf star such as our Sun, the primary reaction is believed to be the proton-proton cycle, in which hydrogen nuclei fuse into helium nuclei. However, studies done in recent years question this supposition, asserting that the proton-proton cycle involves the release of neutrinos (neutral, massless, high-energy particles) as part of the reaction. Fewer neutrinos than expected, however, have been detected, and it's not known whether this is the result of experimental error, prediction error, or stellar core inactivity.

In larger stars, with their higher core temperatures, the CNO (carbon-nitrogen-oxygen) cycle is dominant. Either fusion process liberates energy by changing a small amount of mass into energy. In the proton-proton cycle, about 0.007 grams of matter are converted to energy for each gram of hydrogen processed into helium. Every second, the Sun converts 4 million

By Bradley Wells, KR7L, 1290 Puget Drive East, Port Orchard, Washington 98366

tons of solar matter into 400 trillion trillion watts of energy and radiates it into space.

30,000-year trip

Most of the energy generated within the core of the Sun heats its photosphere, the bright surface layer of gas that radiates the visible light of the Sun. The energy that heats the photosphere today, however, was generated eons ago.

The gas within the Sun's core, compressed to a density 150 times that of water, prevents radiation from traveling directly to the Sun's surface. The movements of photons within the Sun's interior move in a highly erratic motion known as "random walk" (rather than straight-line free flight). The thermal radiation associated with the 15 million degrees Kelvin temperature of the solar core is hard* X-rays, which move an average of only half a centimeter before they crash into a material particle and are absorbed or scattered in a completely different direction. Through this process, these X-rays are gradually degraded into optical photons with lower energy levels. Consequently, it takes 30,000 years for a photon to "walk" out of the Sun; a photon in free flight, on the other hand, would be freed in 2 seconds. Thus, the current appearance and activities of the photosphere were determined by the core conditions some 30 millennia ago.

The temperature of the photosphere can be determined from the following relationship:

$$T = \frac{0.290}{W} \tag{1}$$

where W = wavelength in cm, and
T = temperature in degrees K.
Since the wavelength of maximum radiation in the solar spectrum is 5.1×10^{-5} cm, this corresponds to a temperature of 5700 degrees Kelvin.

The apparent sharply defined surface of the Sun is attributable to changes in the opacity of its surface gas. The gas at the bottom of the photosphere has a high proportion of negative hydrogen ions that obstruct light, causing high opacity. A few hundred kilometers above this layer, near the top of the photosphere, negative hydrogen ions are fewer; this renders the gas clearer and less opaque. Most of the Sun's light comes from this layer. This layer — where photons make the transition from "walking" to flying — is very thin, measuring only 0.1 percent of the Sun's radius. Because it's thin, and because of its abrupt changes in opacity, it appears as a sharply defined surface, just as cumulus clouds in the sky appear to be solid.

* X-rays have wavelengths (10^{-7} to 10^{-10} cm) which are considerably shorter than visible light. Hard X-rays are at the short wavelength end of that 1000:1 spectrum. — Ed.

The gases of the Sun and solar atmosphere comprise a plasma, often referred to as the fourth state of matter. Relatively rare on Earth, plasma normally exists only in regions of extreme temperatures and is composed of positive ions and free electrons, although it's electrically neutral in bulk composition. In the magnetic fields of the Sun, these ions and electrons cannot move freely, but must stream in directions dictated by magnetic lines of force. For this reason, much of the solar atmosphere moves in particular patterns following twisted and intricate magnetic fields.

Photographs of the solar surface show a pronounced granulation. Each of these "grains" is a convection cell measuring 1000-2000 km across, rising at a vertical rate of 2 to 3 km/sec, and lasting only a few minutes. The dark areas between grains mark the regions where cooled gas descends again into the Sun. Large-scale patterning of individual granules is called supergranulation; this involves areas some 30,000 km in diameter, with gas flowing horizontally toward the outer edge of each cell. Surging motions, with wavelengths of 5000 km and periods of 5 minutes, have been observed within these areas.

Between these areas of supergranulation are spicules, small needle-like structures that form the lower half of chromospheric loops and are best seen on the limb of the Sun, where they appear in emission. Since the temperature is too high or the density is too low to scatter much light in the upper part of the loop, these portions tend to remain invisible. Consequently, what is seen of this gas are flames that erupt and fade in periods lasting from 2 to 5 minutes. They form a transition from the photosphere to the overlying chromosphere, the lower layer of the solar atmosphere. Visible to the naked eye during a total eclipse as a ring of small, intense red flames encircling the Sun, the chromosphere is about 2500 km thick, and the temperature in its upper regions exceeds 10,000 degrees Kelvin.

the corona

Above the chromosphere is the solar corona, a pale glowing halo of gas surrounding the Sun. Gas density here is very low, having dropped by a factor of 10,000 from the photosphere to the chromosphere and again by 10,000 between the chromosphere and the lower corona. Like the chromosphere, the corona is normally visible to the naked eye only during a total eclipse. This region emits only one millionth the amount of light produced by the photosphere, yet its temperature is 1 to 2 million degrees Kelvin.

When gases are heated, they become ionized, losing one or more electrons. In the corona, hydrogen and helium are essentially bare nuclei, while the electron shells of heavier elements are severely depleted. This

high degree of ionization is one characteristic of extremely high temperatures.

These high temperatures were deduced from early spectroscopic studies. For a number of years, however, this evidence was discounted because it apparently violated the second law of thermodynamics, which states that heat cannot spontaneously flow from a cool object (the photosphere at 5700 degrees Kelvin) to a hotter one (the corona at 1 to 2 million degrees Kelvin). So fundamental was this objection that for several decades physicists refused to accept spectroscopic analysis at face value. Finally, in the 1940s, the idea of a truly hot corona was accepted and progress was made in coming to terms with this apparent contradiction. It now appears that magnetic effects and shock waves from subsurface convection are responsible for the transfer of large amounts of energy to the corona.

Early photgraphs of the corona taken during total eclipses showed it as a bland sphere of gas whose shape was dependent upon the phase of the solar cycle. During the years of high solar activity, it completely surrounded the Sun. In years of minimal activity, it was concentrated along the equator, with little gas visible in the polar regions. More recent studies conducted at a variety of wavelengths, particulary ultraviolet and X-ray, confirm this phenomenon and also show that the corona is not static, but rather an area of complex activity and turbulent motion.

Transient features of the corona include loops, streamers, and holes that seem so prevalent that some astronomers believe there may be no such thing as a "quiet" corona. Coronal features may be even more transient than once believed. Multiple photographs taken during any solar eclipse provide some evidence of movement in these features even during this very short period of time.

magnetic field has major influence

Individual loops and streamers suggest the patterns formed when iron filings are sprinkled near a magnet. The structure of the Sun's magnetic field imposes itself on the coronal gas. The interaction of this gas and the Sun's magnetic field is governed by the basic laws of electromagnetism. A charged particle in a magnetic field is subjected to a force that depends on its charge, its velocity, and the strength of the magnetic field. Only components of the particle's motion that are at right angles to the field are affected, with the net result that charged particles move in helical paths around the magnetic lines of force. Put another way, a particle is free to move in the direction of the field, but if it's pushed at right angles to the field, it moves in a circle rather than in a straight line. Thus, charged paticles in a magnetic field are said to be "frozen" to the field, and free to move only in the direction of the field's lines of force.

Since the coronal plasma is highly ionized, the corona is an excellent electrical conductor and can sustain large electric currents. These currents, in turn, give rise to magnetic fields that modify the original magnetic fields. This two-way interaction gives the corona a complexity that is simply unavailable in a nonconducting gas.

Studies have indicated that transient events, such as coronal loops, may be uplifted by magnetic buoyancy. Regions with strong magnetic fields are buoyed up by the surrounding gas within the corona. These loops may suddenly become unstable and rise rapidly through the corona. Causes of this instability may be the random motion of photospheric gas at the base of a magnetic loop or the response to a violent photospheric event such as a solar flare.

generation of solar wind

Since magnetic loops are bound to the solar surface at both ends, there's no way for the coronal gas in these loops to escape into interplanetary space. However, in the regions where the Sun's magnetic lines of force stretch infinitely outward, the solar wind can escape along these field lines. It's now believed that much of the solar wind material, especially the high-speed streams, originates within these coronal holes.

Coronal transient events may provide another avenue for escape of material into space. If a closed loop becomes unstable, it can rise and expand to the point at which its field lines open up, ejecting material from the Sun. Observations have also revealed the existence of coronal "bullets" — knots of cool, dense material that are accelerated through the corona and may contribute to this outflow from the Sun.

sunspots

Sunspots are the Sun's most obvious surface feature. Very large groups may be visible to the naked eye, particularly when the solar disk is obscured by thin clouds or fog.

A sunspot is essentially a broad, shallow depression in the photosphere. The umbra, or central floor of the depression, appears dark because its temperature is 1700 degrees Kelvin below the temperature of the surrounding photosphere. At this lower temperature, it emits only one-quarter the light of the surrounding gases. It's believed that the lower temperatures associated with the umbra are due, in part, to intense magnetic fields, first discovered by observation of Zeeman splitting in spectral emission lines.* Individual

* Splitting of the line spectrum of a light source by the influence of a magnetic field. — Ed.

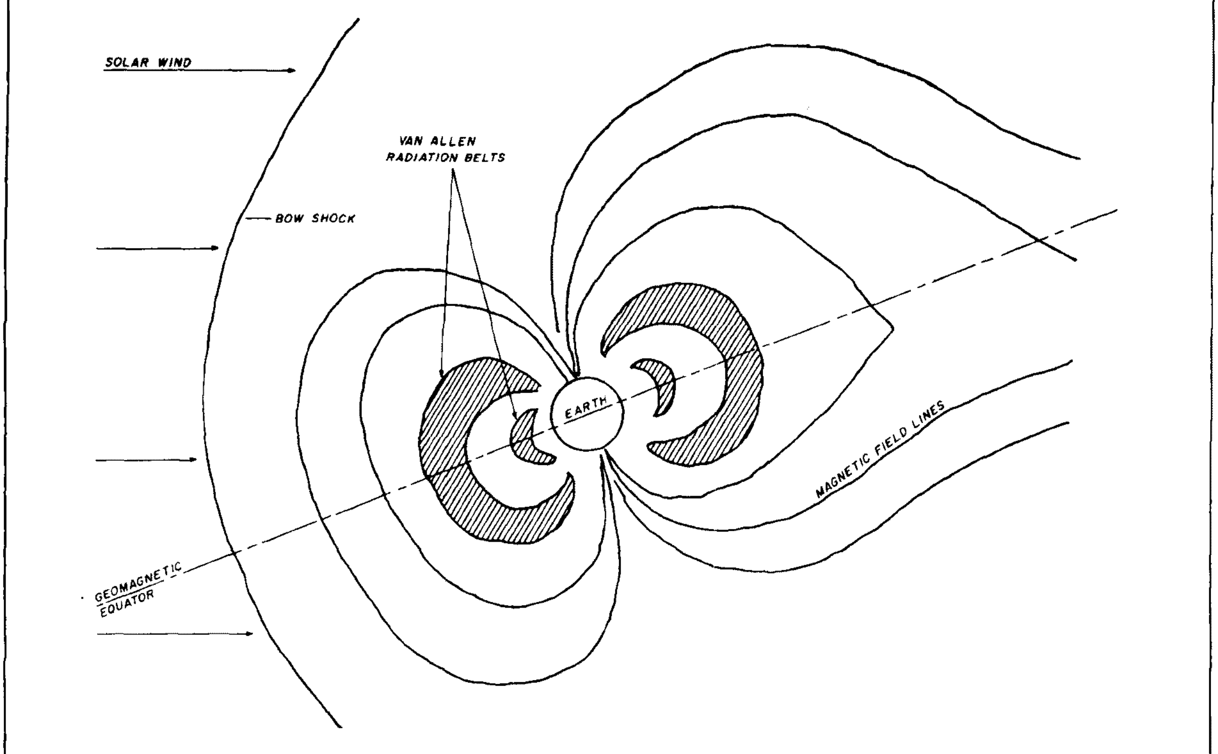


fig. 1. How various types of radio bursts may be produced by solar flares.

magnetic fields, centered in the umbra, have a typical intensity of 3000 gauss* and are confined and compressed by the surrounding gases. Magnetic fields of this strength can be duplicated on a small scale within a laboratory environment. It's interesting to note that in such a field it's nearly impossible to maintain your grip on a metallic object; a wrench or screwdriver will literally tear itself out of your hand and slam up against one pole of the magnet.

The sunspot umbra is surrounded by the penumbra, a gray striated border of material that slopes up and outward from the umbra to the surrounding photosphere. The magnetic field emerging from the umbra spreads out across the penumbra. At some distant point, this field is again compressed and reenters the solar surface, often in a neighboring sunspot of opposite magnetic polarity. As the magnetic lines of force arch up between the two sunspots, a "moat" — an area outside the sunspot, beneath the magnetic arch, that is essentially free of any magnetic influence — sometimes forms.

Sunspots are normally found in bipolar groups with opposite magnetic polarities. Their magnetic fields normally run east and west and are of opposite polarities on either side of the solar equator. The differential rotation of the Sun is the mechanism thought responsible for this. Because the Sun behaves as a fluid rather than solid sphere, surface rotational velocities vary with distance from its equator. The time required for one complete rotation ranges from 27 days in equatorial regions to 33 days near the poles. This unequal movement drags the entrapped magnetic lines of force around, under the solar surface, winding them tighter and tighter. The formation of sunspots, with their associated disturbances, begins to disrupt these fields. They become increasingly chaotic and, eventually, are neutralized as a new cycle of opposite polarity begins.

sunspot cycle

Individual sunspot groups may last from a few weeks to several months. The first spots in a new 11-year cycle appear in a broad band centered around the 40-degree north and south latitudes. As the cycle progresses, succeeding new spots migrate toward the equator. The regions of sunspot formation die out as they approach the equator and, simultaneously, sunspots of a new cycle appear at midlatitudes.

Huge clouds of gas called prominences are ejected from these sunspot regions. There are two types:

* Compare this to the considerably smaller magnetic field surrounding the Earth. — Ed.

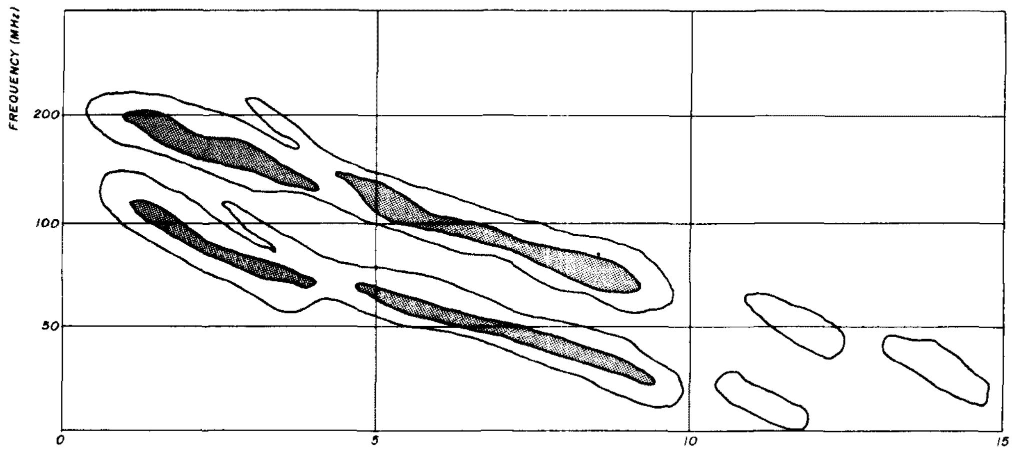


fig. 2. Model of a shock wave and ejecta some 6 minutes after the explosive phase.

eruptive and quiescent. Eruptive prominences move outward from the photosphere with velocities of 1000 km/sec. Quiescent prominences are masses of flowing gas held in relatively fixed positions above the Sun for hours or days by constraining magnetic fields.

flares

The largest blasts of energy and material on the surface of the Sun are flares. A single large solar flare may release the explosive power of 100 million hydrogen bombs, each with a yield of 100 megatons. Flares are normally observed in the light of hydrogen or ionized calcium. The largest, called "white-light" flares, are visible to the naked eye. All involve the high-speed ejection of material from the surface of the Sun. Not visible to optical telescopes is the cloud of electrons ejected by a flare, which is detectable only by radio telescope.

The regions of the Sun where flare energy is released are probed most directly by observation of centimeter radio emissions (listen to WWV at 18 minutes after the hour for the solar flux — 10.7 cm numbers) and the detection of hard X-rays. Continued observations at these wavelengths has led to some understanding of pre-flare conditions and flare activity. Pre-flare buildup is observed at centimeter wavelengths as small areas of increased brightness that exhibit shifts in polarization. At times, these regions show polarization increases of 100 percent and brightness temperatures of 10 million degrees (a measure of radio intensity rather than actual temperature).

Three types of flare models, each with their own distinctive magnetic structure (**fig. 1**), have been proposed. In one type, currents run along field lines arranged in isolated loops to form a sheared magnetic field capable of producing instabilities. The second type involves current sheets at the interface of two loops having opposite magnetic polarities. The third type offers large-scale current sheets between open magnetic field lines. The variation of radio wave polarization with time indicates the primary release of energy occurring by magnetic reconnection in very localized areas. This energy release is rapid, being distributed throughout the magnetic loop in less than 10 seconds. In every case, the size and shape of the magnetic field undergoes major transformations an hour or so before a flare, with the primary release of energy occurring in the upper portions of isolated loops.

The progress of a flare (**fig. 2**) may be divided into two phases. In the first, the visually observable flare appears with strong emissions in the hydrogen (Balmer) alpha line (6560 Å units, red light) and is accompanied by the ejection of an electron jet at velocities up to half the speed of light. As they recede from the Sun, these particles are slowed through interactions with the solar magnetic field and the surrounding solar atmosphere. During this initial phase, X-rays and centimeter radio waves are generated in the region of the optical flare. As the flare moves upward through the layers of the solar atmosphere, radio energy is detected at progressively longer wavelengths. This "synchrotron" radio emission originates as these relativistic electrons spiral in the magnetic fields. The initial radio energy from a flare is designated as a Type II radio burst; it serves as the chief diagnostic tool for investigation of flare activity and the solar corona. Type II bursts (**fig. 3**) are characterized by narrow bands of intense radio emission that drift slowly toward lower frequencies. Generally composed of a fundamental frequency and second harmonic, this dual-frequency emission is characteristic of oscillations within a plasma.

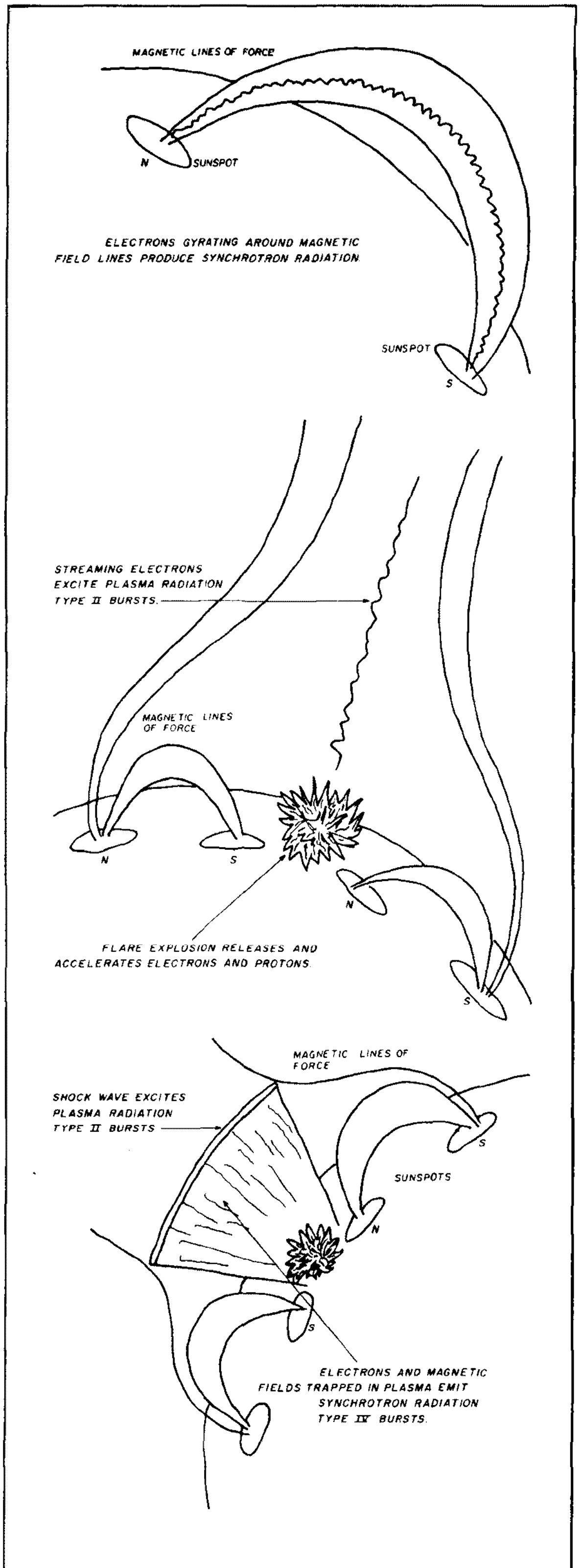


fig. 3. Contour plot of solar radio burst and its second harmonic (flux level proportional to gray scale).

The natural vibration frequency of a plasma is directly related to its electron density. Density decreases with altitude above the Sun's surface; therefore, the lower the frequency, the greater the height of origination above the photosphere. The velocity of a shock wave can be determined by its frequency drift; shock wave velocities up to 3000 km/sec have been observed.

The shock front formed by a solar flare is believed to be quite thin, averaging only 1000 km from front to back. As such, it will move through a given point in the solar atmosphere in less than a second. Shock fronts form only when the wave velocity exceeds a critical value called the Alfven velocity, which is to magnetic waves what the speed of sound is to acoustic waves. It is determined by the strength of a region's magnetic field and electron density.

In the second phase of flare activity, a gas cloud moves up behind the electron jet, but at a much lower velocity. If this material is expelled at a speed greater than 500 km/sec, it will also generate a shock wave that expands outward ahead of it. Since the solar atmosphere has a relatively low density and strong magnetic field, this shock wave becomes a fast-moving magnetic disturbance rather than the more familiar pressure wave. Rising through the corona, it generates radio emission at the leading edge of the cloud as it pushes through the tenuous solar atmosphere. The ejection of this material is also accompanied by a Type IV radio flare, which takes the form of broadband emission over a wide range of frequencies.

During a solar flare, the total visible radiation changes by much less than 1 percent; however, ultraviolet and X-ray radiation may increase a hundredfold. When this radiation strikes the ionosphere, it changes the amount and distribution of free electrons. These shifts in electron density, in turn, affect the refractive characteristics of the ionosphere.*

Although the radio output of the Sun is very small in comparison to its output at visible wavelengths, radio output is highly variable and tends to follow the 11-year solar cycle. During a large flare, the radio energy of the Sun may increase a millionfold for short periods.

In spite of this increased activity outside the visible spectrum, the radiative output of the Sun remains relatively constant, with short-term variations of less than 1 percent. This energy amounts to 1400 watts per square meter at the distance of the Earth. Small-scale, long-term variations in this "solar constant" follow the 11-year sunspot cycle and other, longer, less easily determined cycles.

delay effects of solar "bombardment"

Solar particles ejected from the Sun travel much

* Which, of course, is the main focus of our attention. — Ed.

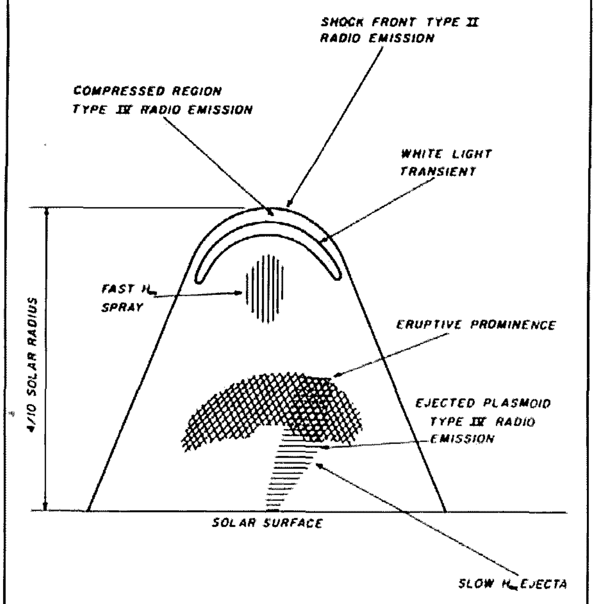


fig. 4. Earth's magnetosphere as charted by satellites.

more slowly than its electromagnetic radiation. It takes some 24 to 36 hours after an event before they impinge on the upper atmosphere, changing its chemistry and creating aurorae.* These colored, swirling patterns of light are visible around the Earth's north and south magnetic poles.

Magnetic fields from the surface of the Sun are frozen into the solar wind and drawn out by the flow. The magnetized plasma of the solar wind cannot easily penetrate the closed magnetic field of the Earth. Consequently, as the solar wind encounters the Earth's magnetosphere, a shock wave (fig. 4) develops. This bow shock, formed 60,000 km on the "upwind" side of the Earth, is analogous to the shock wave that forms in front of an aircraft moving at supersonic speeds. However, the Earth's bow shock isn't fixed in position, but moves back and forth in response to pulses of energetic particles streaming out of the Sun. Beyond this wave, the solar wind plasma flows much more slowly around the Earth's magnetic field.

the Van Allen belt

If captured by the Earth's magnetic field, particles from the Sun form two doughnut-shaped belts or rings around the Earth. These were discovered in 1958 by James Van Allen, using particle counters aboard Explorer 1, the first United States satellite. The inner Van Allen belt is about 2500 km and the outer Van Allen ring is about 15000 km above the Earth's magnetic equator. Particles temporarily stored in these

* This helps explain short-term F2 layer enhancement followed a day or two later by higher absorption — as experienced on 80 meters, for example. — Ed.

belts oscillate back and forth along the lines of force of the Earth's magnetic field. Eventually they leak out the ends of these magnetic "bottles" and into the Earth's atmosphere. Here, these ions collide with upper atmosphere air molecules, causing spectral emission lines whose color is determined by the elements and collision energies involved.

The Van Allen belts are one manifestation of the interaction of the Earth's magnetosphere with the solar wind. The supply of ions and electrons forming the Van Allen belts is continuously replenished by the solar wind. By the time it reaches the Earth, this wind has a density of 5 ions per cubic centimeter and moves with an average velocity of 500 km/sec (about a million miles per hour). These values increase dramatically during periods of intense solar activity.

The electrons circulating in the Van Allen belts also generate an enormous amount of radio energy. This synchrotron radio emission may reach power levels of 1 billion watts at frequencies between 100 and 300 kHz. Fortunately, the ionosphere forms a normally effective barrier preventing radio energy with wavelengths greater than 100 meters from reaching the Earth's surface. It's interesting to note that Grote Reber, the amateur radio astronomy pioneer, constructed a large dipole array in Tasmania which can "see" through the ionosphere at a wavelength of 300 meters on the occasional nights when the electron density of the ionosphere falls to abnormally low values.

The ability of the various layers within the ionosphere to refract radio energy is determined by a number of factors. The time of day, season of year, phase of the sunspot cycle, transient solar events, and the Sun's core conditions 30,000 years ago all affect hf radio communications *at this moment*. The continued study of the Earth's magnetosphere and the Sun's atmosphere may eventually allow us to forecast, with increasing certainty, the hourly state of the ionosphere and its impact on hf communications.

bibliography

1. Briggs, John, "Shortwave Detection of Solar Flares," *Sky and Telescope*, November, 1984, page 452.
2. Foukal, Peter, "Magnetic Loops in the Sun's Atmosphere," *Sky and Telescope*, December, 1981, page 547.
3. Hartmann, William K., *Astronomy: The Cosmic Journey*, *Wadsworth Publishing Company*, Belmont, California, 1978.
4. Kraus, John, *Our Cosmic Universe*, *Cygnus-Quasar Books*, Powell, Ohio, 1980.
5. Kundu, M.R., "Probing The Radio Sun," *Sky and Telescope*, July, 1982, page 6.
6. Maffie, Paolo, *Beyond The Moon*, The MIT Press, Cambridge, Massachusetts, 1979.
7. Maran, Stephen, "The Sun's Violent Flares," *Popular Science*, June, 1981, page 66.
8. Maxwell, Alan, "Solar Flares and Shock Waves," *Sky and Telescope*, October, 1983, page 285.
9. Moore, Patrick, *The Rand McNally New Concise Atlas of the Universe*, Rand McNally and Company, New York, New York, 1978.
10. Parker, E.N., "The Sun," *Scientific American*, September, 1975, page 43.
11. Shields, John, "Backyard Radio Astronomy," *Astronomy*, March, 1982, page 75.
12. Shu, Frank H., *The Physical Universe*, University Science Books, Mill Valley, California, 1982.
13. Stafford, Edward, *Sun, Earth and Man*, NASA, Washington, D.C., 1982.
14. Van Allen, James, "Interplanetary Particles and Fields," *Scientific American*, September, 1975, page 161.
15. Wild, J.P., "Radio Waves From the Sun," *Scientific American*, June, 1955, page 40.
16. Wolfson, Richard, "The Active Solar Corona," *Scientific American*, February, 1983, page 104.

ham radio

better frequency stability
for the Drake TR7

Adding a circuit board improves performance without affecting appearance

Although the TR7 has a rather stable VFO, it can still be improved. With this modification, its stability becomes comparable to that of synthesized frequency generators; consequently, it becomes more useful in the following ways:

- If you're operating on AMTOR, retuning is not necessary.
- Your operating frequency is stable within a second or so after switch-on, even in a cold shack.
- The frequency setting remains stable for an indefinite length of time, making the rig usable for remotely controlled installations such as AMTOR repeaters.

Improved frequency stability is achieved by means of a Digital Automatic Frequency Control (DAFC) circuit. A frequency counter with a crystal-controlled reference measures the frequency to be stabilized. If the count is above or below a defined fixed value, a dc voltage controlling a varicap within the VFO is altered so as to counteract any frequency deviation. The divider ratios used in this design produce a series of stable frequencies which are separated from each other by 30.5 Hz. Actually, the frequency slowly varies about the *nearest* 30.5-Hz point. This is because the output is either too low or too high, but never exactly on. That's why the control voltage continues to hunt.

These fluctuations are generally not noticed when operating in CW, SSB, AMTOR, or RTTY. If you connect a frequency counter, you can see that the VFO frequency excursions amount to not more than ±10 Hz. PA0KSB has designed a circuit that can be incorporated into existing VFOs; he describes the theory behind this kind of frequency control in detail in reference 1.

The present circuit provides VFO frequency control by applying the correcting voltage to the RIT-line. This also enables a possibly connected external VFO to be frequency controlled when switched on.

The reference frequency used is the TR7's 500-kHz signal drived from the 40-MHz main crystal reference, thereby eliminating the need for a separate crystal oscillator. PA0KSB's circuit uses a pointer instrument to indicate the tuning voltage and an UP/DOWN switch for manual control of this voltage.

I wanted to find a way to avoid drilling holes into the front panel of the transceiver for additional switches and a meter. The TR7 already has UP/-DOWN keys; when you depress the STORE key, the UP/DOWN keys are assigned to the DAFC circuit for as long as the STORE key is held down. The rest of the time the UP/DOWN keys perform their usual functions. This means that the initial function of the STORE key can no longer be used — a sacrifice which is more than justified by the advantages of the DAFC circuit. But I couldn't find a way to have the S-meter indicate the DAFC control voltage; instead I adopted an idea proposed by K6EHV.[2] Two lamps indicating the upper and the lower limit of the control voltage are sufficient to display this information. The FIXED lamp (the *upper* one) indicates that the control voltage has exceeded its upper limit. The SET BAND lamp (the *lower* one) shows that the control voltage has gone below its lower limit. Besides being DAFC indicators, both lamps still serve their traditional purpose; in normal operation the control voltage does not reach either limit, so the double use of the lamps presents no problem.

circuit description

The circuit for this modification is shown in **fig. 1**.

By Urs Hadorn, HB9ABO, Im Riedtli 1, CH-8154 Oberglatt, Switzerland

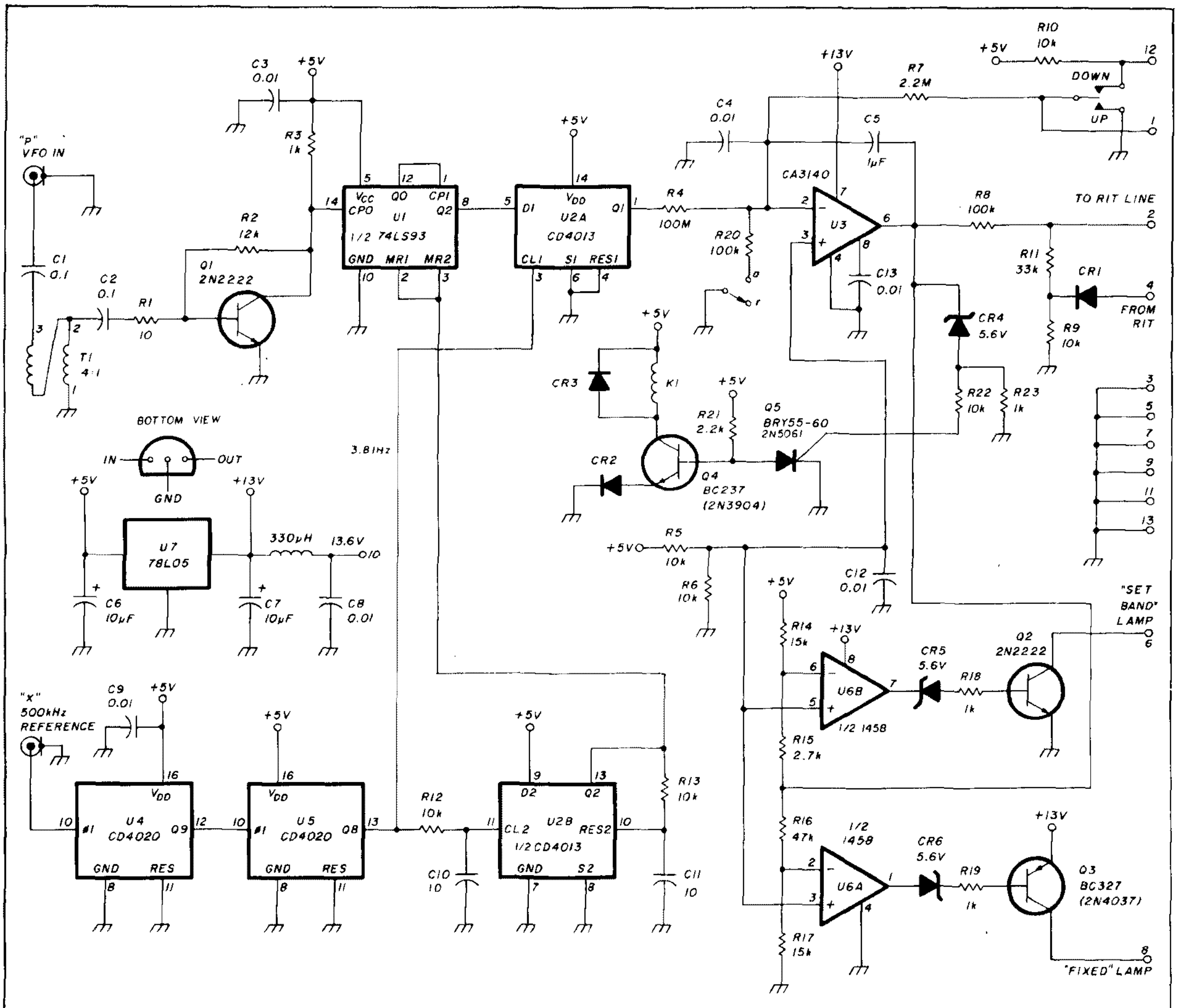


fig. 1. TR7 frequency correction schematic diagram.

The VFO signal enters the DAFC circuit at terminal P. A broadband autotransformer, T1, steps down the signal to match it to the low impedance input of Q1, where it is amplified to TTL level to enable it to drive the frequency counter chip U1. U1 divides the VFO frequency by 8. After each counting period, the count (1 bit) is stored in U2A and the counter is reset to zero. The binary counters U4 and U5 divide the 500-kHz reference by 2^{17}, thus establishing the counting period of 262 ms. A short time (determined by R12, C10) after the rising edge of the counter clock, U2B generates the reset pulse for the counter. The reset pulse width is given by R13, C11. The integrator U3 transforms the 1-bit count result into a slowly rising and falling dc voltage which is used to control the VFO frequency. The integrator time constant is established by R4 and C5. This control voltage and the former RIT voltage entering the circuit at terminal 4 are combined via R8 and R11. The resulting dc voltage is put onto the RIT line at terminal 2 for the VFO in use (internal or external). CR1 and R9 reduce the original RIT voltage so that the combined voltage looks like the former RIT voltage when RIT and DAFC voltages are at mid-range. The integrator output voltage, and with it the VFO frequency, can be raised or lowered manually by applying either +5 volts or 0 volts via R7 to the integrator input.

The circuit associated with thyristor Q5 ensures that the integrator output voltage starts at mid-range at power-up. After switch-on, Q4 conducts, thereby pulling the integrator input down via R20 and the relay contact to ground. U3's output voltage rises at a rate determined by R20 and C5. As soon as it reaches approximately 6 volts, SCR Q5 fires and cuts off the

relay driver Q4, which releases the integrator input by floating R20. This mechanism is not repeatable because Q5 remains on (i.e., conducting) via R21 until the power is turned off.

The two op amps of U6 are used as comparators. The upper comparator drives Q2 into saturation when the integrator output voltage drops below the lower limit of about 2 volts. Q2 turns on the SET BAND lamp. The lower op amp drives Q3 and with it the FIXED lamp when the output voltage rises above the upper limit of about 10.5 volts.

construction

Component layout is not critical. I have built several versions of this circuit mostly using Veroboard. Follow sound rf construction techniques in the area of T1, Q1, and U1: provide a low impedance common ground, keep leads short, and pay attention to shielding. The components used are easy to obtain and low in cost. Impedance transformer T1 is wound on a ferrite toroid core (Philips Part No. 4322 020 97170) with an OD of approximately 0.37 inch and an ID of approximately 0.22 inch. There is no reason why other suitable types — for example, an Amidon FT37-63 or FT37-67 — could not be used.

The winding consists of ten turns of a twisted transmission line you can make yourself. Stretch out a 23.6-inch length of enameled copper wire with a diameter of about 0.016 inch (AWG 26) to smooth out any bends, then cut it in half. Using a hand drill, twist the two pieces to obtain about five turns per inch. Wind ten turns of this transmission line on the toroidal core, taking care that the windings are equally spaced on the circumference. Then connect one end of one wire with the opposite end of the other wire. This connection is the low impedance port (2) of the transformer. The other two ends form the high impedance input (3) and the ground end (1), respectively. They may be interchanged without any effect because the transformer is symmetrical.

The relay may be replaced by a 12-volt type, in which case it has to be connected to the 13.6-volt bus. The capacitor at C5 should be a polystyrene or similar type. Electrolytic or tantalum capacitors would exhibit too much leakage at this point of extremely high resistance. To keep the height of the pc board low, we used three 0.33-μF capacitors instead of one 1-μF capacitor. The voltage divider chain for the comparators (R14, R15, R16, R17) should be selected to be within 2 percent of nominal value to define the range limits of the control voltage accurately.

initial tests

The completed circuit board should be tested before it's incorporated into the transceiver. The following hints assume that there are no leads and signals connected, except for the 13.6-volt supply and those mentioned. When removing and replacing ICs, be sure to disconnect the power supply first.

power supply

Remove all ICs except regulator U7. Verify that there is + 5 volts at the regulator output. Check whether there is 2.5 volts at pins 3 and 5 of U6. The current drain from the 13.6-volt supply should be around 10 mA. Insert all ICs. The current drain should now be around 30 mA.

integrator

Remove U2. After power is connected, the relay should actuate momentarily and drop out immediately. The output voltage at pin 6 of U3 should be in the vicinity of 6 volts. Connect terminal No. 1 of the board to ground (corresponding to a depressed UP switch). The output voltage of U3 should rise within a few seconds to 11 volts. Connect terminal 1 with terminal 12, (corresponding to a closed DOWN circuit). The output voltage of U3 should decrease within a few seconds to about 0.1 volts.

comparators

The following maneuvers are performed by manipulating the UP and DOWN contacts as described above. Lower the integrator output voltage, starting from 6 volts. When the 2-volt level is crossed, output pin 7 of U6 should jump from 2 volts to about 12 volts.

Raise the integrator output voltage, starting from 6 volts. When the 10.5-volt level is crossed, output pin 1 of U6 should jump from 12 volts to about 2 volts.

time base

Remove U2. Apply the 500-kHz signal to terminal X. (You may use either the 500-kHz signal from the TR7 or a signal from another source. In any case, it should be a square wave of 4 to 5 V_{pp}.) At pin 13 of U5 there should be a square wave of 3.81 Hz.

frequency counter

Remove U2, grounding pins 2 and 3 of U1. Connect the VFO signal (from the main board of the TR7) to terminal P. At pin 8 of U1, you should now detect a square wave measuring one-eighth of the VFO frequency. You can verify this by connecting the DAFC terminal P to the VFO line of the main board; doing this should cause just a minor drop of the VFO (PTO) voltage in the TR7.

installation

The DAFC circuit board is mounted to the lower side of the main board as shown in **fig. 2**. Insert a sheet of flexible pressure-resistant insulating material between the two soldered sides. The circuit board and

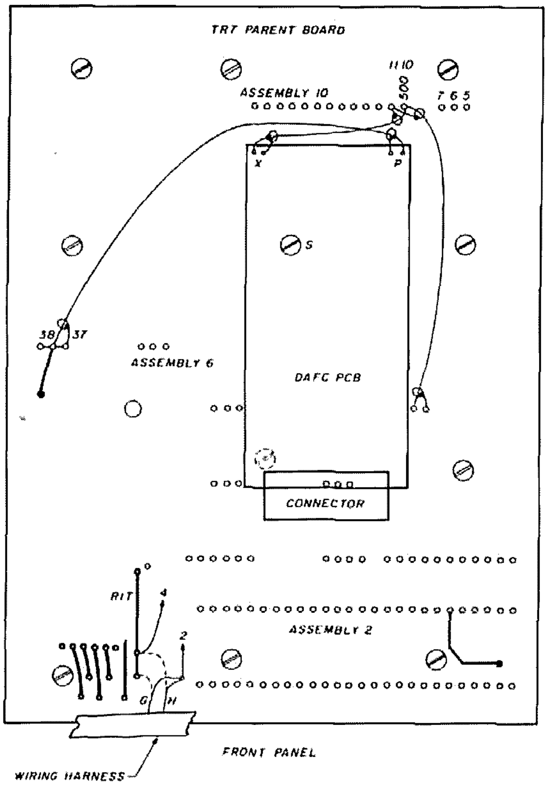


fig. 2. Positioning of the DAFC PCB on the TR7 main board and arrangement of the different connecting points.

Parts list for digital AFC:

C1,C2	0.1 μF
C3,C4,C8,C9, C12,C13	0.01 μF
C5	1 μF (or three 0.33 μF)
C6,C7	10 μF 16 V
C10,C11	10 pF
CR1,CR2,CR3	1N4148
CR4,CR5,CR6	5.6-volt Zener 1N708A or 1N4626
K1	Reed relay
L1	330 μH ferrite choke
Q1,Q2	2N2222
Q3	BC327 or 2N4037
Q4	BC237 or 2N3904
Q5	BRY55-60 2N5061
R1	10 ohms
R2	12 k
R3,R18,R19	1 k
R4	100 megohms
R5,R6,R9,R10, R12,R13,R22	10 k
R7	2.2 megohms
R8,R20	100 k
R11	33 k
R14,R17	15 k
R16	51 k
R21	2.2 k
U1	74LS93
U2	CD4013BE
U3	CA3140
U4,U5	CD4020BE
U6	CA1458
U7	LM78L05

the insulating sheet are fixed to the main board by means of a screw (S in **fig. 2**) and two insulating spacers, each about 0.08 inch thick. To be on the safe side, insulate the bottom cover of the TR7 with insulating tape or sheet. The connection of the board to the TR7 is via a 13-pin connector and two small-diameter coaxial cables. (See **photo B.**)

switch wiring

Label all applicable wires before modifying (see **fig. 3**). After identifying wires A through F, unsolder all connections from the three switches and remove the spring hook from the STORE switch so that it can no longer lock when depressed. The new wiring of the switches is shown in **fig. 4** and **fig. 5**. Wire F of the former STORE function is no longer used. Insulate its dead end and bend it into a safe place. The two wires from D2a and S2m are dressed together with the wire from the FIXED RCV switch towards the bottom side of the main board. The various connections to the DAFC board are shown in the figures, with their respective connector numbers circled.

connections on the main board

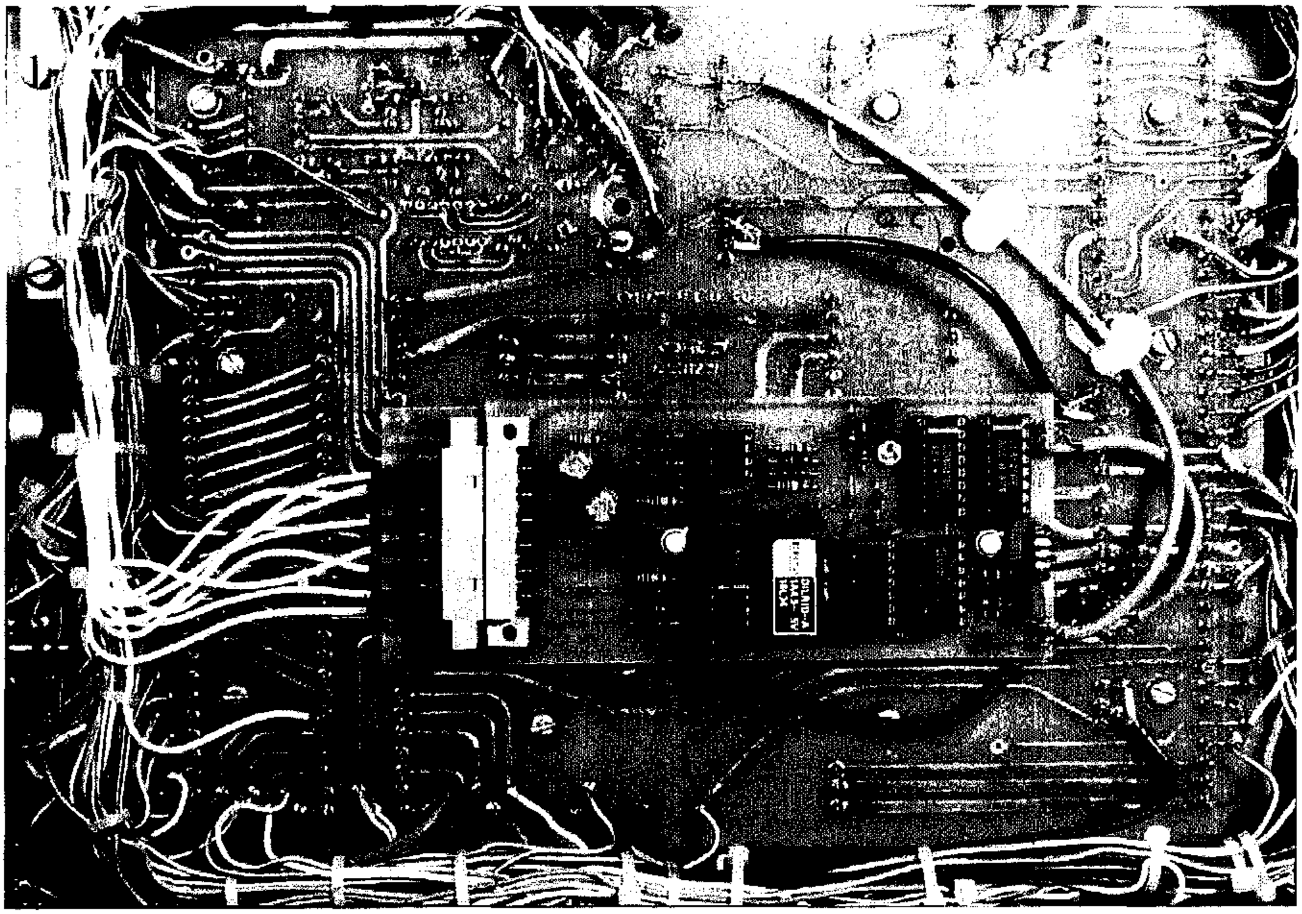
Figure 2 shows the bottom side of the TR7 main board. The connecting points which are used to install the DAFC board are labeled with assembly and pin numbers according to the TR7 service manual. The power supply board is not part of the main board; it is located to the left of the main board between the PA radiator and the rf and a-f gain controls. The 13.6-volt supply voltage is picked up from pin 9 (counted from the left) of the power supply board. The RIT control voltage is available on the conductor labeled RIT in **fig. 2**. In the original wiring the RIT voltage is run from this conductor to the internal and external VFOs with one wire each.

Two wires (labeled G and H) have to be removed from the RIT conductor and connected instead to the DAFC connector, pin 2. The RIT conductor is connected to DAFC connector, pin 4. This completes the installation. It might now be necessary to realign the RIT control center setting according to the service manual (section 3.16).

To gain confidence in this modification, zero-beat a strong a-m broadcast station. Switch on the passband tuning at its center position to allow for maximum response at the carrier center frequency. Try the best zero-beat setting you can obtain; it will be somewhere between 0 and 15 Hz. Don't worry if you hear a rather unsteady beat note. The fluctuations are in the order of a few Hz — less than you will ever notice in one of the stability-sensitive operating modes. If you leave the rig untouched and check in after hours or even days, the beat note will still be moving back and forth, but will be near the same 30.5 Hz point — and by the same few Hz!

operation

This DAFC circuit controls any undesirable frequency excursions under 2 kHz. If the drift exceeds this range, one of the two lamps — either FIXED (upper limit) or SET BAND (lower limit) — will light to announce that the DAFC cannot compensate for any further drift. It is obvious that with the inherent stability of the TR7 VFO, this condition is not very likely to occur. Holding down STORE momentarily DOWN



Closeup shows new board placement and wiring in the TR7.

162

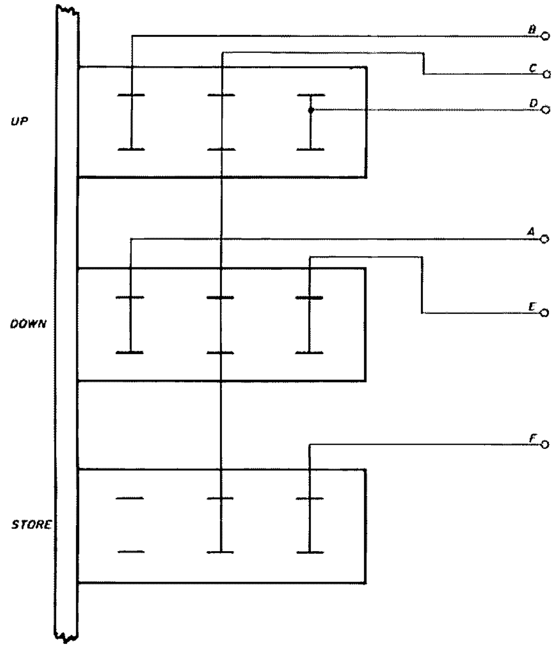


fig. 3. Original wiring of the UP, DOWN, and STORE keys.

163

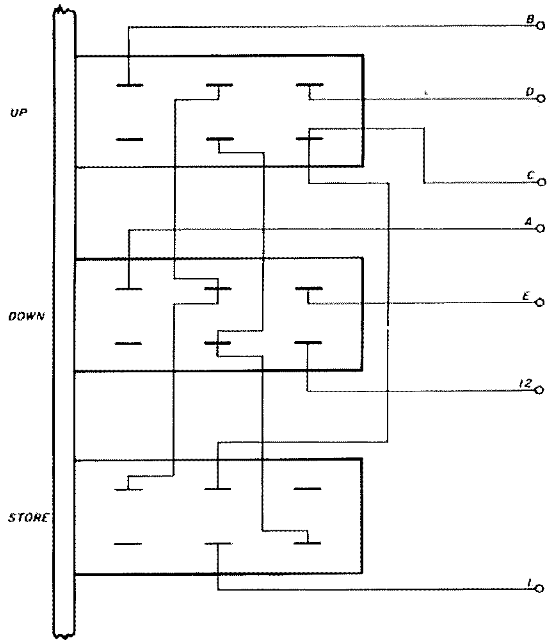


fig. 4. Modified wiring of the UP, DOWN, and STORE keys.

or UP, as is appropriate, brings the DAFC voltage back into its operating range. (UP and DOWN can also be used as a fine tuning, but I think the main tuning knob does a better job.) After several months of operation with more than one modified TR7, the range limits were never reached. It is therefore left to the reader to decide whether to build the circuit with or without the comparator stage and with or without making the connections to the lamps and switches. Tuning behavior and the traditional functions of the UP and DOWN keys are not impaired at all by the DAFC.

limitations

When operating with RIT switched on, you have to take into account that after an RX/TX/RX transition it is not necessarily true that the frequency will be on the same 30.5-Hz spot as it was before. The DAFC has no means of remembering previous voltage/fre-

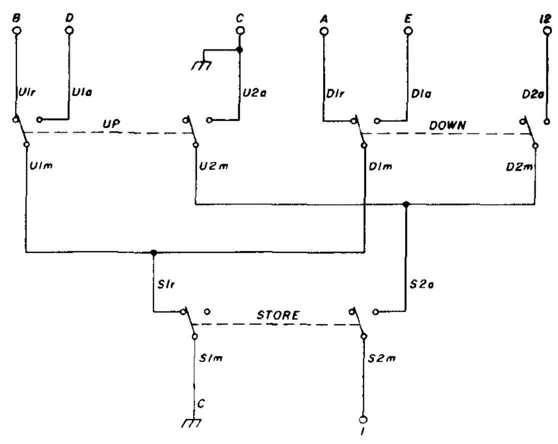


fig. 5. Modified circuit of the UP, DOWN, and STORE keys.

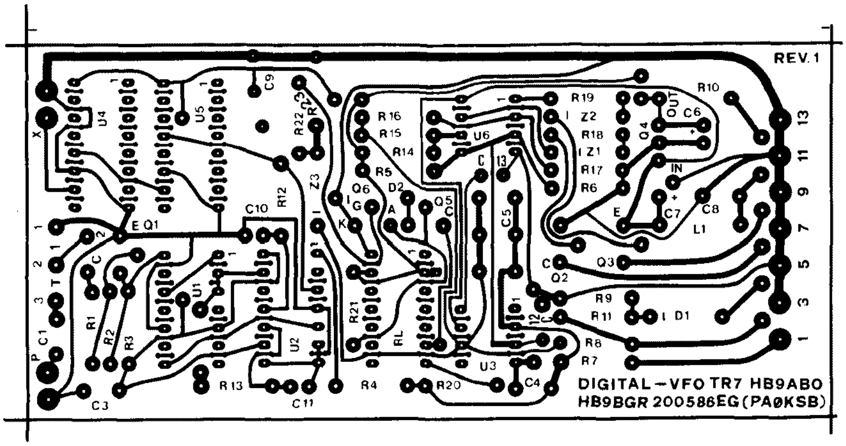
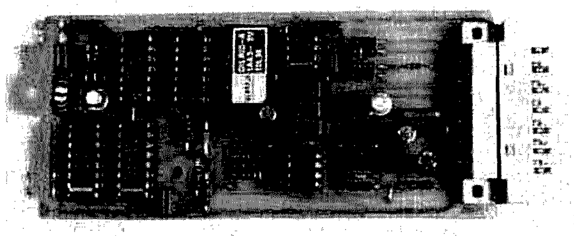


fig. 6. TR7 frequency correcting circuit pc board (foil side).

Table 1. Interconnections between the board and the transceiver. (See figs. 2 and 5.)

designation on DAFC board	connector pin number	Destination within TR7
VFO (PTO) signal (P)	-	assembly No. 06, pin 38
braid (coax VFO)	-	assembly No. 06, pin 37
500-kHz reference (X)	-	assembly No. 10, pin 10
braid — 500 kHz	-	assembly No. 10, pin 11
13.6-volt supply	10	assembly No. 21, pin 9 (power supply board)
RIT voltage from RIT circuitry	4	conductor labeled RIT
RIT output voltage	2	to wires G and H
+5 volts via R10	12	DOWN switch lug D2a
integrator input via R7	1	STORE switch lug S2m
SET BAND lamp	6	assembly No. 02, pin 6
FIXED lamp	8	FIXED RCV key
ground	3, 5, 7, 9, 11, 13	ground solder lug near assembly No. 21



Frequency correcting circuit improves TR7 stability.

quency conditions once the controlling voltage has been changed externally. (That's what happens when RIT is in operation.)

After the power is turned on, you might occasionally hear a short chirp. This is caused by the control voltage being driven into mid-range. Because there are spurious responses at 21266.7 and 28050.0 kHz due to harmonics of the VFO frequency generated by the nonlinear amplifier at Q1, it is important to use good shielding at that stage.

conclusion

Working with the modified TR7 is very rewarding: no longer is there any need to warm up before a sked. Just switch your rig on and tune in. Should a frequency difference arise during a QSO, you can be confident that it's caused by the other station's equipment!

Although this modification isn't difficult, it's a good idea to review references 1 and 2 as well as the TR7 service manual. Doing so will help you understand what you're doing at every step along the way.

Materials for this project can be obtained from HB9BGR (Charlie Egli, HB9BGR, Rümelbachstrasse 9, CH-8153 Rümlang, Switzerland). A list of available items, with prices (U.S. currency, air mail delivery included), follows.

Printed circuit board, undrilled	$12.00
Drilled circuit board	$15.00
Kit with all components and undrilled PCB	$61.00
Kit with all components and drilled PCB	$64.00
Assembled and tested unit	$92.00

For those who wish to etch their own full-size printed circuit board, artwork is provided in **fig. 6**. Follow the foil side labels and detail shown in the photos for parts placement.

references

1. "Drift Correction Circuit for Free-Running Oscillators," Klaas Spaargaren, PA0KSB, *ham radio*, December, 1977.
2. "AFC Circuit for VFOs," by Read Easton, K6EHV, *ham radio*, June, 1979.

ham radio

BASIC program analyzes simple ladder networks

BASIC or PASCAL — which is best for you?

This article is written in response to a recent article discussing a compiled PASCAL network analysis program.[1] The author of the PASCAL program contended that a network analysis program written in an interpreted language such as BASIC would result in unacceptably long execution times; he also claimed that BASIC doesn't lend itself to structured programming techniques. The intent of this article is to offer an alternative viewpoint and to demonstrate a simple and useful BASIC network analysis program.

The main fault with the BASIC language — from the programming teacher's point of view — is that BASIC lends itself to unstructured programming techniques, and consequently, self-taught programmers (most of us) tend to start writing code without having worked out the overall structure of the program. This is not a fault of the BASIC language, but of the programmer. A BASIC program can be just as well structured as a PASCAL program, but this is seldom so because one can start writing BASIC code without worrying about how it will finally end! In fact, that is why Dr. Niklaus Wirth developed the PASCAL language — to *force* the programming student to use good structuring techniques. However, this forced method of programming is of little interest to the Radio Amateur wanting to learn only enough about programming to perform some network analysis on relatively simple ladder circuits.

The contention that BASIC programs have unacceptably long execution times is subjective and relative; that is, if you are required to analyze circuits on a daily basis, a reduction in calculation time of more than half is very important. If you want to analyze only a few circuits with some minor modifications now and then — and if a tabular output instead of a graphical output is sufficient — then it doesn't matter too much whether the calculations take 5 seconds or 20 seconds per run. Consequently, a slower, non-compiled BASIC network analysis program may be quite satisfactory. The BASIC network program discussed in the following article will permit *ham radio* readers to decide which network approach they prefer.

simple vs. complex BASIC programs: — which do you need?

Although many powerful and versatile BASIC network analysis programs have been published in the electronics trade journals, the length and complexity of these programs make them unattractive.[2,3,4,5] Instead of considering these more complex programs, why not first try the following simple BASIC program to see if it meets your requirements?

short BASIC program solves simple ladder networks

Computer analysis of a proposed circuit is preferable because many circuit variations can be more quickly and conveniently evaluated by computer than by actual circuit construction and measurement. The BASIC program discussed in this article permits you to evaluate networks consisting of alternating single-element shunt and series branches, such as Chebyshev high-pass or low-pass filters. By using "null" branches, the program can also evaluate more complex networks with series-tuned series branches or parallel-tuned shunt branches. You can specify the actual measured component values and *Q*s so you can be assured that your circuit, when properly assembled, will perform the same as your computer model.

BASIC listing

Figure 1 is a listing of a BASIC network analysis program that requires less than 3K of memory and is short enough to be entered into your computer at one sitting. Because of its simplicity, the program can't analyze networks having a parallel-tuned circuit in a series branch or a series-tuned circuit in a shunt branch. Elliptic low-pass and high-pass filters are examples of the circuits this program cannot analyze.

Ed Wetherhold, W3NQN, Honeywell Inc., Signal Analysis Center, P.O. Box 391, Annapolis, Maryland 21401

```
10 REM Written by W3NQN on SANYO MBC-550 computer using MS-DOS BASIC, Ver. 1.1. For publication in HAM RADIO.
20 REM Program gives filter Atten (dB) vs. Freq (MHz) for simple ladder networks with equal source & load resistances.
30 REM RL=Load resistance. List first branch starting at load end with shunt element or a null shunt branch.
40 REM  List in Data Statements  TYPE (1=R, 2=L, 3=C),  VALUE (ohms, uH or pF) and  Element Q (1E10 = no loss).
50 DIM M(15), X(15), P(15) : PI=3.14159 : RL=50 : FU=1E+06 : LU=.000001 : CU=1E-12 : REM Max. branches = 14.
60 DATA -3,1100,1E10 : REM Negative sign indicates prior null shunt branch in filter network shown in Figure 2.
70 DATA  2, 1.75, 1E10
80 DATA  3,  560, 1E10
90 DATA  2, 1.75, 1E10
100 DATA 3, 1100, 1E10
110 DATA -1,  50, 1E10 : REM Negative sign indicates a null branch prior to resistor.  For a resistor, 1E10 does
120 DATA 0, 0, 0        : REM  not refer to Q.  The 1E10 is used only to maintain a proper data READ order.
130 INPUT "ENTER FREQUENCY START (MHz),  STEP (MHz),  NO. STEPS";  FS, ST, NS
140 FOR N=1 TO 15 : READ M(N), X(N), P(N) : IF M(N)=0 THEN 160
150 P(N) = 1/P(N) : NEXT N
160 PRINT "Output data in Pairs" : PRINT "Freq (MHz)  Atten. (dB)"
170 FOR FX=FS TO FS+(NS*ST) STEP ST : REM  Selected range of test freqs (MHz) and start of FOR/NEXT loop.
180 OM=2*PI*FX*FU : BR=1 : BI=0 : DR=0 : DI=0 : CR=RL : CI=0 : K=0 : N=0 : F1=0
190 K=K+1 : N=N+1 : MK = M(N) : IF F1>0 THEN MK = -MK
200 F1= 0
210 GOSUB 360
220 IF K=1 THEN V1 = AR : REM AR = Real (Resistance).
230 IF K=1 THEN V2 = AI : REM AI = Imaginary (Reactance).
240 IF MK= 0 THEN 370
250 IF MK< 0 THEN 280
260 ON MK GOSUB  290, 310, 330
270 GOTO 190
280 CR=0 : CI=0 : N=N-1 : F1=1 : GOTO 190 : REM Null Branch.
290 CR=X(N) : CI =0 : IF K =INT(K/2)*2 THEN RETURN : REM Resistor.
300 CR = 1/CR : RETURN
310 CI = OM*X(N)*LU : CR = CI*P(N) : IF K=INT(K/2)*2 THEN RETURN : REM Inductor
320 DD = P(N)*P(N)+1 : CR =P(N)/DD/CI : CI = -1/DD/CI : RETURN
330 CI = OM*X(N)*CU : CR = CI*P(N) : IF K=INT(K/2)*2 THEN 320 : REM Capacitor
340 RETURN
350 REM  Complex Linear Update -
360 AR=BR*CR-BI*CI+DR : AI=BI*CR+BR*CI+DI : DR=BR : DI=BI : BR=AR : BI=AI : RETURN
370 IF K=INT(K/2)*2 THEN 390
380 AR=BR : AI=BI : BR=DR : BI=DI : DR=AR : DI=AI
390 DEM= V1^2 + V2^2 : RNUM= DR*V1 + DI*V2 : REM Following calculations for Freq (MHz) vs. Atten (dB).
400 INUM = DI*V1-DR*V2 : RTXF = RNUM/DEM : ITXF = INUM/DEM
410 MTXF = 1/(SQR(RTXF^2 + ITXF^2)) : ATXF = -2*ATN(ITXF/(MTXF + RTXF))
420 AA = -20*(LOG(2)/LOG(10)) - 20*LOG(MTXF)/LOG(10) : REM Filter Atten (corrected for source resis V-drop).
430 PRINT USING "####.## " ; FX; : IF AA>1 THEN 450 : REM  Prints Freq (MHz) to two decimal places.
440 PRINT USING "  .#### " ; AA : GOTO 460 : REM Formats output for Atten less than one dB.
450 PRINT USING "  ###.#  " ; AA :          REM Formats output for Atten greater than one dB.
460 NEXT FX : END : REM Program ENDS after completion of FOR/NEXT loop.
```

fig. 1. Listing of BASIC network analysis program for attenuation vs. frequency.

However, the program can analyze all networks consisting of alternating shunt and series branches composed of single elements, or those networks that can be configured to simulate alternating single-element shunt and series branches by the insertion of null branches. The BASIC program was derived from a listing found in reference 6.

using the program

Starting at the load end of the network and progressing towards the voltage source, the coding for each component TYPE, VALUE, and Q is entered in separate program DATA statements in the same order the components appear in the network. The coding of all DATA statements starts with a number indicating the component type (1 = resistor, 2 = inductor, or 3 = capacitor), followed by a second number indicating the component value (ohms, μH, or pF) and concluding with a third number indicating the component Q.

This program always expects to start with a shunt branch across the load. Consequently, the coding in the first DATA statement must be for a shunt branch. However, if your circuit has no shunt branch across

the load, then a negative sign must immediately precede the coding of the first series branch TYPE number to indicate to the program that there is a prior null shunt branch. Whenever there is a prior null branch (either series or shunt), a negative sign must be placed before the next component TYPE number.

The next-to-last DATA statement is the coding for the source resistance, and it must have the same value as the load resistance. For this program listing, a 50-ohm load and source resistance is used, but you may change this value by changing RL in **line 50** and the source resistance in the DATA statement. The DATA statements conclude with 0,0,0 to indicate to the program that all data entries are completed. An example will demonstrate the coding of the network components and the running of the program.

design application and network analysis example

Assume we want to protect an 80-meter direct-conversion receiver from overload caused by a nearby 1-MHz broadcast transmitter. Measurements showed that an attenuation of 50 dB at 1 MHz eliminates the receiver overload. A five-element Chebyshev standard-value capacitor (SVC) high-pass filter with a cutoff frequency of 3.37 MHz is selected from table 16 of reference 7. The schematic diagram of this filter (design No. 54) and the frequencies at the 3-, 20-, and 40-dB attenuation levels are shown in **fig. 2**. We will use the network analysis program to find the expected attenuation at 1 MHz to see if this filter design is suitable.

The analysis program shown in **fig. 1** requires that the network branches be listed in the DATA statements starting with a shunt element at the load end, but because this high-pass filter configuration does not have a shunt element across the load, we must simulate in the DATA coding the null branch indicated by the dashed box in **fig. 2**. The first branch coding entered in the DATA statement is for a 1100-pF capacitor. The first number in the coding is a negative 3 to indicate to the program that a prior null branch exists, and that the following series branch is a capacitor. The 1100 indicates the capacitance in pF and the 1E10 indicates *no loss*. This completes the coding for the first DATA statement. For this first example, we will assume all components have no loss. The coding for the remaining components is entered into the DATA statements in a similar manner, concluding with the series source resistance (with a negative sign because the previous shunt branch was a null). A DATA statement with three zeroes indicates to the program that it has worked back to the network's voltage source and that the input element (the source resistance) has been processed. Note that this program considers the source resistance to be part of the network being analyzed. See **lines 60** to **120** in **fig. 1** for the coding of the network illustrated in **fig. 2**.

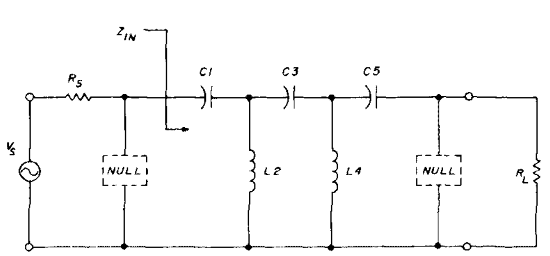


fig. 2. Schematic diagram of 50-ohm Chebyshev high-pass filter.

After the DATA statements are completed, the program is run and the responses to the prompts for FREQUENCY START and STEP (both in MHz) and NUMBER OF STEPS are entered. For our evaluation, we start at 1 MHz with steps of 0.2 MHz, and enough steps will be used to provide frequency and attenuation data to 4.2 MHz. The output for this run is shown in **fig. 3A**. The filter attenuates the broadcast transmitter signal at 1 MHz by 52.9 dB, but this was for perfect components. Let's see if the filter attenuation at 1 MHz is still adequate when we assign typical *Q*s of 1000 and 150 to the capacitors and inductors, respectively.

After the *Q* values are changed in the DATA statements, the program is run again; the output is shown in **fig. 3B**. We see there is less than 0.4 dB change in attenuation between 1 and 4 MHz (between the filters that use ideal rather than real components) and therefore the filter should provide the required attenuation when built with real components.

Note that the validity of the program's operation is confirmed by checking the frequency and attenuation output values of the program against the published frequencies at the 3-, 20-, and 40-dB attenuation levels shown in **fig. 2**. This was done with frequency increments of 0.01 MHz and component *Q*s of 1E10. **Figure 3C** shows the results of runs covering the frequencies corresponding to the 3-, 20-, and 40-dB attenuation levels. Because the program's calculated frequency and attenuation data (for no-loss components) are essentially identical to the data in **fig. 2**, it means that the network analysis program is functioning correctly, and it may be used with confidence.

additions and refinements

The program listing in **fig. 1** gives only attenuation vs. frequency data; however, input impedance (Z-input) vs. frequency of the filter network is also often desired. To obtain Z-input vs. frequency, the program in **fig. 1** is modified by adding **line 470** and by chang-

output data in pairs freq (MHz)	atten (dB)
1.00	52.9
1.20	44.5
1.40	37.2
1.60	30.8
1.80	24.8
2.00	19.3
2.20	14.2
2.40	9.4
2.60	5.2
2.80	2.2
3.00	0.6974
3.20	*0.1490*
3.40	0.0136
3.60	0.0011
3.80	0.0118
4.00	0.0199
4.20	0.0217

output data in pairs freq (MHz)	atten (dB)
1.00	52.9
1.20	44.5
1.40	37.2
1.60	30.8
1.80	24.9
2.00	19.4
2.20	14.3
2.40	9.5
2.60	5.4
2.80	2.5
3.00	0.9274
3.20	*0.3432*
3.40	0.1743
3.60	0.1375
3.80	0.1316
4.00	0.1280
4.20	0.1212

freq (MHz)	atten (dB)
2.72	3.2
2.73	3.1
2.74	3.0
2.75	2.8

freq (MHz)	atten (dB)
1.96	20.4
1.97	20.1
1.98	19.9
1.99	19.6

freq (MHz)	atten (dB)
1.30	40.7
1.31	40.4
1.32	40.0
1.33	39.7

fig. 3. Program outputs for five frequency scans. (A) Both the inductors and capacitors are considered lossless. The run time is 25 seconds. (B) A capacitor Q of 1000 and an inductor Q of 150 are assumed. (C) Closer response examination around 2.74 MHz. (D) Closer response examination around 1.97 MHz. (E) Closer response examination around 1.32 MHz.

```
160 PRINT " Freq.  Z-Input  Phase  R-Input  X-Input":PRINT " (MHz)  (ohms)  (deg)  ---- (ohms) ----"



390 AI=BR*BR + BI*BI  :  AR=(DR*BR + DI*BI)/AI  :  AI=(DI*BR - DR*BI)/AI : REM Sub-routine for Z-input.
400 AR=AR-RL        : REM Removes source resistance from Z-in calculation.
410 PRINT USING "###.## ";FX;              : REM Frequency (MHz).
430 PRINT USING "  ####.#" ; SQR(AR^2 + AI^2) ; : REM Z-input magnitude (ohms).
440 PRINT USING "   ####.#" ; ATN(AI/AR)*180/PI; : REM Phase angle (degrees).
450 PRINT USING "   ####.#" ; AR ;          : REM Real part (ohms).
460 PRINT USING "  #####.#" ; AI            : REM Imaginary part (ohms).
470 NEXT FX : END
```

fig. 4. Listing of changes to fig. 1 program to get Z-input vs. frequency.

ing lines **160** and **390** to **460**, as shown in **fig. 4. Figure 5** shows an output run using this Z-input subroutine. In addition to the input impedance magnitude, the impedance phase and the resistive and reactive components of the impedance are calculated and tabulated. (Those wishing to calculate both the attenuation and Z-input of the network should combine the appropriate lines for the two subroutines within the analysis program.)

The program in **fig. 1** can be used to analyze filters in the audio-frequency range if the inductance and capacitance units in **line 40** and in the DATA statements are changed to millihenries and nanofarads, and if the frequency unit "MHz" is changed to "kHz" in lines 20, 130, 160, 170, 390, and 430. If these changes are made to the program, the DATA statements are correct for a 50-ohm, 3.37-kHz high-pass filter, and the same attenuation vs. frequency data listed in **fig. 3A** applies to this filter, except the frequency unit in the table heading is kHz, not MHz.

The output statements of the programs shown in **figs. 1** and **4** direct the calculated results to the CRT

Freq. (MHz)	Z-Input (ohms)	Phase (deg)	R-Input ---- (ohms)	X-Input ----
1.00	133.2	-90.0	0.0	-133.2
1.20	106.5	-90.0	0.1	-106.5
1.40	86.6	-90.0	0.1	-86.6
1.60	70.6	-90.0	0.0	-70.6
1.80	57.2	-89.9	0.1	-57.2
2.00	45.2	-89.7	0.3	-45.2
2.20	33.9	-88.8	0.7	-33.8
2.40	22.5	-85.3	1.8	-22.4
2.60	11.3	-65.6	4.7	-10.3
2.80	11.5	11.1	11.2	2.2
3.00	26.6	26.5	23.8	11.8
3.20	41.0	17.6	39.1	12.4
3.40	48.6	6.2	48.3	5.2
3.60	50.0	-1.8	50.0	-1.6
3.80	49.0	-5.8	48.7	-5.0
4.00	47.6	-7.2	47.2	-6.0
4.20	46.6	-7.0	46.2	-5.7

fig. 5. Z-input vs. frequency for the same test conditions used in fig. 3A.

monitor; however, if hard copy is preferred, the user should modify all PRINT statements to cause the table headings and outputs to be directed to the printer. See your printer manual for the proper coding.

precautions to observe when copying the program

When copying the program into your computer, be careful *not to* confuse the number 1 with the letter l or the number 0 with the letter O. After the transfer is completed, be sure to SAVE the program to disk or tape before attempting to RUN it. If you don't save the program, and the program crashes on the first run, you may have to reset your computer and the program will be wiped out. After saving the program, make a trial run for attenuation vs. frequency by duplicating the input parameters shown in **fig. 3A**. If your data output is the same as shown, you have copied the program correctly and it is ready for use. Test the Z-input subroutine the same way if you plan to use it later.

acknowledgment

The author gratefully acknowledges the assistance of Matt Fivash of Honeywell in providing the attenuation vs. frequency program subroutine and for reviewing the manuscript.

references

1. J. A. Koehler, "Top-down Filter Design," *ham radio*, January, 1987, page 41.
2. E. Niemeyer, "Network-Analysis Program Runs on Small Computer Systems," (written in HPL for the H-P 9825 computer), *EDN*, February 4, 1981.
3. R. Steincross, "BASIC Program Performs Circuit Analysis," *EDN*, September, 1982.
4. K. D. Wyatt, "A Ladder Network Analysis Program," *rf design*, November, 1986.
5. B. K. Erickson, "Network Analysis on the Personal Computer," *rf Design*, December, 1986.
6. T. R. Cuthbert, Jr., *Circuit Design Using Personal Computers*, John Wiley & Sons, Inc., 1983, Program B4-1, page 434.
7. *The 1987 ARRL Handbok for the Radio Amateur*, 64th Edition, Table 16, page 2-48. Published annually by the American Radio Relay League, Newington, Connecticut.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

minimum requirements for 2-meter EME: part 1

First postulated in the early 1930s in *Short Wave Craft*, edited by Hugo Gernsbeck,[1] the concept of Earth-Moon-Earth (EME) communications has been around for over 50 years. However, it wasn't until March, 1946, that authenticated echoes were heard off the moon. This was accomplished with a commercial radar operating at approximately 112 MHz.[2] Amateurs weren't successful at using the EME path until 1950, when W3GKP first heard W4AO off the moon on 144 MHz.[3] The first Amateur two-way EME QSO didn't occur until ten years later, when W1BU contacted W6HB on 1296 MHz on September 12, 1960[4]; four years after that, OH1NL and W6DNG completed the first 2-meter EME QSO, on April 12, 1964.[5]

EME communications differs from conventional propagation in one major way: the time it takes the signal to reach the other station. In conventional terrestrial propagation, if a signal circumscribes the Earth (such as on the long path) and returns to the point of origin, it will do so in less than 140 milliseconds or one-seventh of a second (excluding, of course, the mysterious long delay echoes, or LDE). Since this is a relatively short time period, it's difficult for the average Amateur to determine whether the signal transmitted ever arrived at the desired destination. (This is the so-called "dead band" or "black hole" syndrome — was the band open, or was there just no one listening in Tibet?)

Because the distance to the moon is always greater than 221,450 miles (356,375 km) from the Earth, a radio signal traveling from the Earth to the moon and back will always take at least 2.38 seconds to complete the trip! Therefore, if you listen and hear your echo return from the moon, you can be sure your equipment is functional, propagation is favorable, and you are definitely completing the desired path.

EME communications is maturing rapidly. Only a decade ago it took a sizable commitment in time, money, and effort to be successful on EME. That is no longer true for the following reasons:

- Suitable equipment — either homebrew or commercial — is now readily available.
- On August 29, 1983, the FCC raised the USA Amateur power limit to 1500 watts output (versus 1000 watts dc input); this represents a potential 3- to 4-dB improvement.
- Improved antennas and antenna systems are now available.
- Many so-called "super stations" are now active.

I still receive many questions about EME and am often asked what band I recommend. Naturally, I'd like to recommend 70 cm (432 MHz), since that's where I began and still continue most of my EME work. However, it's definitely easier to get on 2 meters, where there's a higher concentration of super stations, all states are available, and over 50 DXCC countries have been active. Two meters is a good place to start your EME career, especially if larger antenna systems don't frighten you!

With the first weekend of the ARRL EME contest just around the corner (October 17-18, 1987) I decided to devote this and next month's column to 2-meter EME. This month's column will be primarily an introduction into EME background information and jargon. Next month's will address the minimum requirements for successful 2-meter EME communications as well as the various pieces of equipment required. By the time this material appears, you should be able to set up your own 2-meter EME station with little or no assistance.

terminology

It would be foolish to jump into EME communications headfirst without knowing and understanding the jargon. Some of the more common terms are listed in **table 1**.

Probably the most common one, ***hearing echoes***, means that you can hear your own signal returning from the moon (**fig. 1**). As mentioned, the round-trip time on the EME path is greater than 2.38 seconds. There's plenty of time to send at least one or two letters or numbers on CW or a full call sign on SSB and then listen for your echo.

A related term, ***self-test***, involves listening for your echoes. Whenever you change equipment, you can quickly evaluate the effect of that change on your system by listening to the strength of your echoes. If you can adjust and measure your output power level accurately, you can reduce your transmitter power until your echoes are barely perceptible; you'll now have a reference point for any future changes.

Measuring approximately 2160 miles in diameter, the moon travels around the Earth in a slightly elliptical orbit with an eccentricity of 0.0549. When the moon is closest to the Earth, it is said to be at ***perigee***. At minimum this distance is about 221,450 miles.[6] Perigee occurs once every 25 to 29 days throughout the year,[7] at all phases of the moon during any one-year period, not just at the full-moon phase.

Table 1. Common EME terms (see text).

Echo
Self-test
Perigee
Apogee
Semi-diameter (S.D.)
Finding the moon
Greenwich hour angle (GHA)
Declination
Right ascension
Local azimuth
Local elevation
EME window
See the moon
Common window
Rising or setting moon
European, North American, and Asian EME window
Faraday rotation
Cross polarized
Doppler shift
Libration fading
Scintillation
Ground, sky, and sun noise
Cold sky
Hot spot
Horizon shot
Ground gain

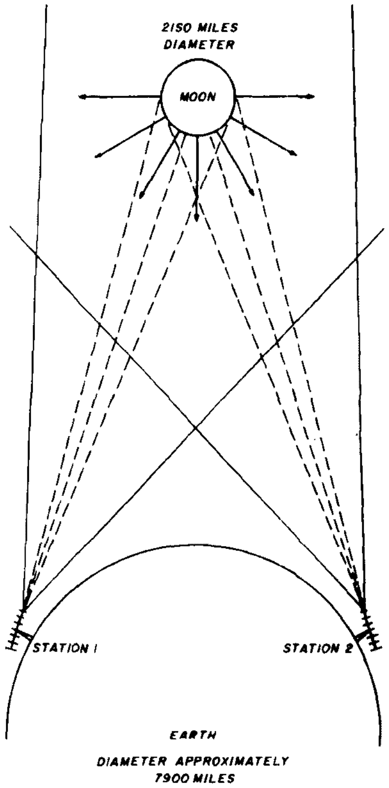


fig. 1. This figure shows the essential elements of the EME path. Note that most of the radiated signal misses the moon entirely. Of the signal that does hit the moon, some is absorbed and the rest scatters in all directions, with only a very small amount arriving back at the point of origin or at any monitoring station.

Since the moon orbits the Earth in a sinusoidal manner, it stays fairly close to perigee for five to seven days at a time. Then the moon rapidly moves away from the Earth, almost like a pendulum, until it reaches ***apogee***, its furthest distance from the Earth. At maximum this distance is approximately 252,736 miles (406,720 km), where the moon also stays for five to seven days. The average distance between perigee and apogee is 25 to 30,000 miles (40 to 48,000 km). Because of this property, EME signals at maximum apogee are attenuated by an additional 1.12 dB on each path direction, or overall about 2.25 dB more than at minimum perigee.

Astronomers often refer to apogee and perigee by the term ***semi-diameter***, or *S.D*; this is the apparent half-width of the moon as viewed from the Earth in minutes of arc. The daily S.D. is shown at the foot of the pages in "The Nautical Almanac."[8,9] Perigee varies greatly throughout the year; typically, it occurs with an S.D. of 16.1 to 16.7, which indicates an apparent arc of 32.2 to 33.4 minutes, or just over half a degree of angular width as viewed from the Earth. Apogee is much more uniform throughout the year, with a typical S.D. of 14.6 to 14.8.

I first published a graph showing the relationship between S.D., perigee, and apogee in the Eimac EME notes.[10] It was later published in reference 9 and has been reproduced in reference 11. **Figure 2** shows a recently revised version.

finding the moon

The moon's position is generally referred to in terms of ***Greenwich Hour Angle*** (GHA) and ***declination***. GHA is the Earth's longitude over which the moon appears to be hovering, referenced to the Greenwich Meridian. The GHA of the moon varies a slight bit less than the rotation of the Earth, or just under 15 degrees per hour.

The moon's declination is referenced to the Earth's equator. Therefore, the declination of the moon represents the angular number of degrees the moon is north or south of the Earth's equator (this is the same as the Earth's latitude). The declination of the moon varies in a sinusoidal manner. Every 25 to 29 days, the moon reaches maximum northerly or southerly declination for five to seven days at a time. Declination changes slowly, seldom varying more than a degree per day at maximum, but with large variations — up to several degrees per day — when going from northerly to southerly declination and vice versa.

The moon's maximum declination is a slow, smooth function of its location with respect to the 18- to 19-year lunar cycle and varies between about 18 and 28 degrees. In the years from 1986 through 1989, we have been and will continue to be near maximum declination. Minimum declination of 18 degrees last occurred between 1977 and 1979 and will occur again between 1995 and 1998.[7]

Sometimes the moon's position may be defined in terms of ***right ascension*** and declination. This is another astronomical coordinate system which locates the apparent position of the moon with respect to the number of degrees east of the vernal equinox and the declination as previously discussed. Right ascension can be expressed in degrees, but is usually expressed in terms of hours and minutes, with one hour representing 15 degrees. Right ascension is often used to determine which portion of the sky or constellation is behind the moon as viewed from the Earth (more on that shortly).

In the good old days, we EMEers used to find the moon either by looking up at the sky and aiming our antennas accordingly or by using the hourly GHA and declination values

shown in *The Nautical Almanac* with the tabular method described in reference 9. For example, if the moon's position was at GHA 66 degrees with a north declination of 18 degrees, 26.5 minutes, we knew it would appear directly overhead in San Juan, Puerto Rico. This was a tedious procedure; sometimes we'd goof, but that was part of the challenge on EME communications.

Later some fortunate EMEers with access to large mainframe computers and moon orbital prediction programs could print out a year's worth of data showing the ***local azimuth and elevation*** angles of the moon every 10 or 15 minutes of the day. With personal computers, that's changed; accurate moon position programs are now available even for the least expensive PCs. One of the most popular is the one written by Lance Collister, WA1JXN. Just input your latitude and longitude and the program displays or prints out your ***local azimuth and elevation*** to the moon as well as the GHA, declination, and right ascension for any day, time, or increment of time desired.* **Figure 3** shows a sample printout; other output data shown will be discussed shortly.

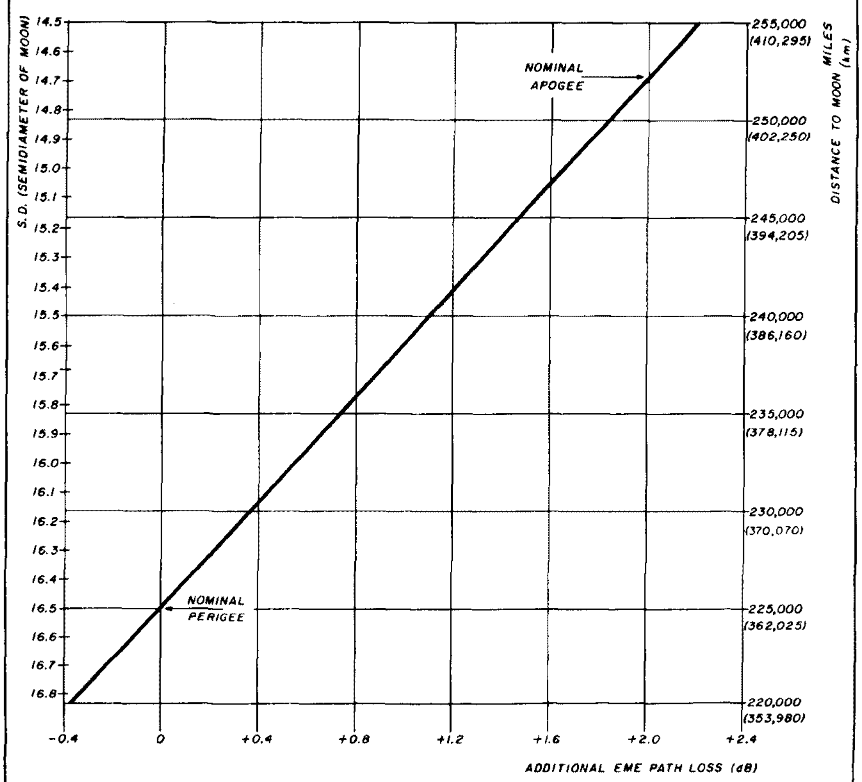


fig. 2. This graph shows the variations in EME path loss versus the distance to the moon. S.D. is the semidiameter, as explained in the text. To find additional attentuation to the moon, draw a line horizontally from either the S.D. or distance side to the pivot line and drop down to the additional path loss.

the EME window

For successful EME echoes, the moon must be above your horizon. You don't actually have to be able to ***see the moon*** for successful EME operation; you just have to be sure that you'd be able to see it if the skies were clear. The moon isn't usually visible to the naked eye — especially in daylight — when it's within one to two days of its new moon phase, but this may still be acceptable for EME operation.

Most EMEers know their local antenna azimuth and elevation limits based on the size of the antenna structure and any local obstructions. They translate these local parameters into GHA and declination limits. If you have a few different days of EME printout, typically one at maximum northerly, one at maximum southerly, and another at zero moon declination, you can easily determine your EME window. Then it's just a simple matter of comparing your window with the window of the station you want to reach to see whether you have a ***common window*** at the desired schedule time. If you do, contacts at distances greater than 10 to 11,000 miles (16 to 18,000 km) are possible.

When 2-meter EME operation took off in the early 1970s, there were many stations using large tropo antenna arrays that were rotatable only in azimuth. Therefore, they could operate EME only when the moon was low on the horizon — usually referred to as a ***rising or setting moon*** — typically below 10 degrees of elevation.

This concept was further expanded and standardized by Bob Sutherland,

*For a copy of this program suitable for IBM compatibles or the Apple Macintosh, send a double-sided, double-density diskette with sufficient return postage to Gene Shea, KB7Q, 417 Staudaher Street, Bozeman, Montana 59715.

short circuits
HW-101 readout

In **fig. 2** (top board schematic) of NU4F's article, "A True-Frequency Digital Readout for the HW 101" (January, 1987, page 8), the connection between the 600-ohm resistor and the 1.0-MHz timing crystal, which goes to pin 6, U5, is also shown connected to the run from pins 1, 2, 4, 5, and 8. This connection should go only to pin 6, U5.

U13 through U16 were omitted from the parts list on page 12; these are 74LS00 Quad NAND gates.

2-meter Yagi

In **fig. 2** of W1JR's May column (see page 95), the spacing of the first director is shown as 26 7/8 inches. This should have been indicated as 26 7/16 inches. According to the author, this discrepancy would probably not affect performance.

W6PO.[12-14] Three windows, the ***European, North American, and Asian EME windows*** were defined. All three required the moon to be at any positive (north) declination.

The start of the European EME window is two hours before the moon sets in Frankfurt, West Germany. The Asian EME window begins when the moon rises above the horizon in Kurume, Japan and ends two hours later. The North American EME window is sandwiched between the European and Asian EME window. Hence, it starts immediately after the European EME window and ends when the Asian window opens. It is centered on a GHA of 116 degrees, which can also be described as the 116-degree west longitude meridian which passes just to the west of Las Vegas, Nevada.

This may all seem confusing and difficult to remember. However, the WA1JXN moon locator program uncomplicates it by incorporating all these windows in the printout. If you look at **fig. 3**, you'll see the letters E, N, and A alongside the printout between 1500 and 2145 UTC. These letters indicate, respectively, the times when you're in the European, North American, and Asian EME window. Simple enough?

path anomalies

So far I've mentioned only the anomalies attributable to the difference in path attenuation. Many others affect not only the returned signal strength, but its quality; these include ***Faraday rotation, doppler shift, libration fading, scintillation***, and ***noise***.

On 2-meter EME, ***Faraday rotation*** is probably the biggest problem. Whenever a linearly polarized electromagnetic wave passes through an ionized region such as the ionosphere, its polarity is shifted or rotated. On EME this is a double problem because signals pass through the ionosphere twice, once on the way to the moon and again on the return. Dick Turrin, W2IMU, has suggested the following rule-of-thumb equation for maximum Faraday rotation one way on 100 MHz and above:[15]

$$\Theta \approx 200/f^2$$

where Θ is the maximum number of degrees of Faraday rotation one-way and f is frequency in GHz. For example, the maximum one-way Faraday rotation on 144 MHz can reach 9645 degrees!

Faraday rotation is usually minimal for a station operating on the equator with the moon directly overhead because the magnetic field in the direction of propagation is virtually zero. Polar stations will be most severely affected since they have to operate at low antenna elevation angles. Hence

Apr 26, 1987
Sunday
JD: 2446911.5

42D 34'58" N
71D 22'35" W
(QTH: FN42HN)

Range: 383,997 km
P + 8 Days 15.56'SD

									144 MHz		432 MHz	
GMT	Notes	W	Az	Elev	GHA	DEC	RT	ASCN	DK	DB	DK	DB
0915			82.6	0.9	338.6	6.3	0H	55M	275	2.5	20	1.3
0930			85.1	3.8	342.3	6.3	0H	56M	276	2.5	20	1.3
0945			87.5	6.5	345.9	6.3	0H	56M	276	2.5	20	1.3
1000			89.9	9.2	349.5	6.3	0H	57M	276	2.5	20	1.3
§			§	§	§	§	§	§	§	§	§	
1430			152.3	51.6	55.0	7.6	1H	6M	282	2.7	20	1.3
1445			158.0	52.7	58.6	7.6	1H	6M	282	2.7	20	1.3
1500		E	164.0	53.6	62.2	7.6	1H	7M	282	2.7	20	1.3
1515		E	170.2	54.2	65.8	7.6	1H	7M	283	2.7	20	1.3
§		§	§	§	§	§	§	§	§	§	§	
1630		E	201.9	53.1	84.0	8.0	1H	10M	284	2.7	20	1.4
1645		E	208.0	52.2	87.7	8.3	1H	10M	284	2.7	20	1.4
1700		N	213.5	50.8	91.4	8.3	1H	11M	284	2.7	20	1.4
1715		N	218.7	49.3	95.0	8.3	1H	11M	285	2.7	20	1.4
§			§	§	§	§	§	§	§	§	§	§
1930		N	253.5	29.7	127.7	8.9	1H	16M	287	2.7	20	1.4
1945		N	256.4	27.1	131.3	8.9	1H	16M	288	2.8	20	1.4
2000		A	259.1	24.5	134.9	8.9	1H	17M	288	2.8	20	1.4
2015		A	261.8	21.9	138.5	8.9	1H	17M	288	2.8	20	1.4
§			§	§	§	§	§	§	§	§	§	§
2130		A	274.6	8.6	156.7	9.2	1H	20M	290	2.8	21	1.4
2145		A	277.3	6.0	160.5	9.5	1H	20M	290	2.8	21	1.4
2200			279.7	3.3	164.1	9.5	1H	21M	290	2.8	21	1.4
2215			282.1	0.5	167.7	9.5	1H	21M	290	2.8	21	1.4

Note: § indicates data omitted.

fig. 3. Sample printout of the WA1JXN EME program as described in the text. Note: Deletions have been made in the interest of brevity. This should not affect the example given in the text.

the direction of travel of radio signals is often parallel to the magnetic field and with a greater path through the ionosphere. Likewise, even stations at the equator and midlatitudes will experience significant Faraday rotation when the moon is at low local elevation angles.

Fortunately, the number of degrees of Faraday rotation are often less, perhaps only 10 percent of the maximum value shown above. The least amount of Faraday rotation occurs late at night, during the winter, and when the ionosphere has low ionization, such as during times when solar activity is at a minimum (1984 to 1986). The polarity of 2-meter EME signals during these times will usually remain constant for up to several hours.

Faraday rotation is most troublesome during daytime and summertime, especially near sunrise when drastic ionization changes take place, and during periods of high solar activity, such as the solar cycle 22 maximum predicted for 1989 to 1992. During these times, 90- to 180-degree polarity changes can sometimes occur as often as every 15 to 30 minutes. Remember that Faraday rotation occurs each time a signal passes through the ionosphere, so at any one station it's double the one-way value.

For example, if Faraday rotation is only one-tenth the maximum value (945 degrees) going toward the moon, it will probably be 1890 degrees when the signal returns from the moon to the point of origin. This just happens to be 5.25 complete polarity rotations (1890/360), and hence the signal arriving at your antenna is now 90 degrees out of phase or ***cross-polarized***, so the chances of hearing echoes at this time are almost nil!

Furthermore, Faraday rotation is nonreciprocal. As a result, the station scheduled may have a different phase shift, which may cause the polarity of the signal to be optimum at one location but not at the other station at the same time. You have to be patient and wait for the polarity to shift back to optimum. (This will be discussed in next month's column.)

There are ways to beat Faraday rotation, but they're all complicated, especially on 2 meters. The most obvious fix is to use circular polarization. However, when a circularly polarized radio signal hits a surface such as the moon, its sense is reversed. Hence a signal transmitted using right-hand sense will return from the moon in left-hand sense and vice versa, thus being cancelled out at the antenna! Furthermore, a station using circular polarization will be penalized 3 dB when receiving or transmitting to a linearly polarized station. The only partial solution is to use linear polarization and devise a scheme to rotate your antenna polarity manually — a difficult job at best. This will also be discussed further in next month's column.

Doppler shift is another EME problem, but not a big one at 144 MHz. As viewed from any one location, when the moon is east of your local longitude, signals have an apparent positive frequency shift with a maximum at moonrise. When the moon is approximately due south (passing over your same longitude), doppler will be minimum to nonexistent and will shift negative as the moon travels westerly, with another maximum at moonset. Maximum doppler shift seldom exceeds about 500 Hz at 144 MHz. Remember that if the longitude of the station scheduled differs from yours, its doppler will also differ. Some tuning may be required to compensate for this change.

Libration fading is a minor problem on 2-meter EME. Basically speaking, the moon appears to rock slightly with respect to an observer on the Earth. Libration is worst when the moon is near apogee and perigee and diurnally when the moon is directly south or crossing your local longitude. If libration fading is severe, it can actually cause fades of up to 20 dB in very short periods of time, sometimes even during a single letter on CW. However, libration fading is more pronounced on higher (e.g., 70 cm) frequency bands.

Scintillation is another sporadic 2-meter EME problem somewhat similar to libration fading. Caused by patches or blobs of ionization in the ionosphere that focus or defocus the signals, it causes fading — especially during winter nighttime and while geomagnetic storms are in progress. At times it can even enhance reception by a few dB for short periods of time. Scintillation decreases with frequency and is seldom observed on 70 cm.

Several types of noise affect EME operation — for example, ***man-made, ground, sky, and sun noise***. Man-made noise is sometimes a problem on 2 meters. If you do encounter man-made noise, it can often be decreased or eliminated with an effective automatic noise blanker on your EME receiver (or i-f if applicable) or by moving your antenna position slightly to null it out.

One of the reasons that EME is so effective on 144 MHz and above is that the local ambient noise is low. At hf, ambient noise is often 10 to 20 dB above that of a receiver looking into a shielded 50-ohm resistor. This can easily be observed. Terminate the antenna input connector on your hf receiver with a shielded 50-ohm resistor and observe the receiver noise. Now disconnect the termination and replace it with an outdoor antenna and observe the increase in noise level. It's not necessary to strive for the lowest noise figure in hf receivers because the local noise would mask internally generated noise. Repeat this same test on 2 meters or above and you may see little or no change indicating low ambient noise.

Noise can be converted to an equivalent temperature. The reference for noise is generally considered to be a temperature of absolute zero, 0.0 degrees Kelvin or −273.16 degrees Celsius (one degree change on the Kelvin scale is equal to one degree change in Celsius). The Earth's temperature is generally considered to be about 290 degrees Kelvin or approximately 17 degrees Celsius.

At 144 MHz, the ***cold sky***, that portion of the galaxy that contributes the least amount of galactic or sky noise, is typically less than 200 degrees Kel-

vin, 98 degrees Celsius below room temperature, or about −73 degrees Celsius. Therefore, if you first aim your 2-meter EME antenna a few degrees below the horizon, note the receiver output noise level and then elevate your antenna to point at one of the colder portions of the sky, all other things being equal, you'll notice a decrease in receiver noise.

Radio astronomers have measured and mapped galactic noise in terms of equivalent noise temperature at several different frequencies using very narrow beamwidth antennas.[15] These maps are now widely available; the 136- and 400-MHz versions were reproduced in one of the Eimac EME notes.[17]

Using these maps, you can find ***hot spots***, areas that have an equivalent noise temperature of over 3000 degrees Kelvin! Aim your antenna at the center of the galaxy in the Milky Way (between the constellations of Sagittarius and Scorpius), and you'll find that your antenna noise temperature will increase significantly. Because the moon moves across the sky once every 28 days, it sometimes passes directly between the Earth and one of these hot spots. C.R. Somerlock, W3WCP, showed a method of calculating your system's degradation based on the sky temperature behind the moon.[18]

Fortunately the hottest spots in the galaxy are very narrow and mostly in the southern hemisphere (southerly or negative declinations), which is not used as much by 2-meter EMEers. Since 2-meter EMEers feel that the noise in these areas significantly degrades performance, they usually avoid making schedules when the moon passes through the higher temperature portions of the sky.

Sky noise maps are usually referenced to right ascension and declination and are therefore cumbersome to use with the normal parameters of GHA and declination. However, Derwin King, W5LUU, and Lance Collister, WA1JXN, have devised tables and incorporated sky noise temperature information into the WA1JXN EME program described earlier. If you look at the sample printout in **fig. 3**, you'll note that the right ascension (RT ASCN) is shown along with the sky temperature in degrees Kelvin at both 144 and 432 MHz for each position of the moon along with potential degradation in dB. This really simplifies calculations.

Sun noise is another minor problem on EME. On a good EME system, your receiver output with a typical EME antenna will increase 6 to 10 dB when your antenna is aimed directly at the sun. Consequently, EMEers don't make schedules when the moon is within about one day of new moon.

Despite its noise, the sun is still an excellent source for antenna and system tests. Generally speaking, the more sun noise you see, the higher the gain of your antenna. To do a sun noise test, first reference your receiver noise output by aiming your antenna at a cold spot in the sky. Then aim your antenna at the sun and measure the increase in noise. One note of caution: sun noise is a function of solar activity, so if you get a very high reading, test at another time when the sun is less active.

You can check your antenna's pointing accuracy at the same time you test for sun noise. Calculate the position of the sun just as you calculated the position of the moon. Sun locator programs are *also* available; one is included on the WA1JXN moon locator program diskette.

horizon shot

As mentioned before, it's sometimes inconvenient for 2-meter EMEers to elevate their large tropo antenna arrays, but they still want to make EME contacts. So these operators keep schedules with the larger stations at their local moonrise or moonset, whichever is applicable.

Horizon schedules are much less reliable because ground noise may limit signal levels. Nevertheless, many EME contacts have been made in this manner. All that's necessary is to set up a schedule when the moon is at less than about 10 degrees of elevation at your location.

If you're very lucky on a horizon schedule, you may get ***ground gain***, which is somewhat analogous to the enhancement reflection you occasionally experience if you observe sunrise or sunset across a body of water. Six to 12 dB (round trip) of enhancement is theoretically possible; this can improve your chance of success significantly. Give it a try. Many stations are willing to run such schedules.

summary

This month's column was essentially a primer on EME communications, with the emphasis on 2 meters. Several techniques for locating the moon were discussed, as well as some of the terminology involved with EME communcations. Next month's column will discuss the minimum requirements and equipment required for 2-meter EME communications. With this information, you can join the fun on the cutting edge of communications technology.

new records

I'm happy to announce that the first Amateur two-way EME contact above 2320 MHz was made on April 7, 1987. Dave Hallidy, KD5RO (EM12KV), operating from Rick Fogle, WA5TNY's QTH, completed a two-way EME QSO on 9 cm (3456.1 MHz) with Les (Lucky) Whitaker, W7CNK/5 (EM15FI), for a distance of 174 miles (280 km). Then WA5TNY joined in to work W7CNK. Three- and 5-meter dishes with relatively low power (100 watts maximum) were used. Congratulations to Dave, Rick, and Lucky, who have been working very hard on this project for some time. Now that the 9-cm band has been scaled, I'll bet this record won't last long!

technical notes available

Dick Turrin, W2IMU, has recently updated the classic *Technical Reports from The Crawford Hill VHF Club*. Primarily devoted to 1296-MHz EME, it includes 20 separate notes dealing with subjects such as system considerations, transmitters, receivers, and antennas for EME. These notes are in-

valuable for the serious UHF and VHF EMEer as well as the microwave specialist. A check for $24.00 ($26.00 outside the United States) made out to Dick Turrin at P.O. Box 65, Colts Neck, New Jersey 07722, will bring a copy by return mail. Because of the high cost of cashing them, no foreign bank drafts can be accepted.

important VHF/UHF events

August 1-2	ARRL UHF Contest
August 1-3	SWOT (Sidewinders On Two) Open QSO Party (contact K5IS)
August 8	EME Perigee
August 12	Predicted peak of the Perseids meteor shower at 1300 UTC.
August 22-23	ARRL 10-GHz Cumulative Contest, first weekend.
September 5-6	International Region 1 VHF Contest, 2 meters only
September 6	EME perigee
September 10-13	Microwave Update '87 Conference, Estes Park, Colorado (contact W0PW)
September 12-14	ARRL September VHF QSO Party
September 21	Optimum time for TE propagation (±2 weeks).
September 19-20	*ARRL 10-GHz Cumulative Contest, second weekend.*

references

1. Bill Orr, W6SAI, "Ham Radio Techniques: Diana to EME in 20 Years," *ham radio*, February, 1981, page 40.
2. Herbert Kauffman, W2OQU, "A DX Record: To the Moon and Back," *QST*, May, 1946, page 65.
3. Edward P. Tilton, W1HDQ, "Lunar DX on 144 MHz!", *QST*, March, 1953, page 11.
4. Edward P. Tilton, W1HDQ, "Coast to Coast Via the Moon on 1296 mc!" *QST*, September, 1960, page 10.
5. Sam Harris, W1FZJ, "U.S. to Europe on Two Maters,"*QST*, June, 1964, page 95.
6. Jean Meeus, "Extreme Perigees and Apogees of the Moon," *Sky and Telescope*, August, 1981, page 11.
7. Berenice L. Morrison, "Perigee and Apogee of the Moon 1959-1999," *United States Observatory Circular No. 130*, April 19, 1971.
8. *The Nautical Almanac*, 1987, United States Government Printing Office, $11.00.
9. Joseph H. Reisert, Jr., W6FZJ/1, "EME Scheduling, When and Where," *QST*, July, 1974, page 25.
10. Joe Reisert, W6FZJ, "An EME Path Loss Nomogram," *Eimac Amateur Service Note 49-2: Moonbounce Operating Aids*, Varian Eimac, Inc., 301 Industrial Way, San Carlos, California 94070.
11. *The ARRL Handbook*, 1987 edition, Chapter 23, "Space Communications"; available from Ham Radio's Bookstore for $18.00 plus $3.50 shipping and handling.
12. Robert I. Sutherland, W6PO, "Universal EME Window for USA and Europe," *Eimac Amateur Service Note 49-2: Moonbounce Operating Aids*, Varian Eimac, Inc., 301 Industrial Way, San Carlos, California 94070.
13. Ken Tentarelli, W1FZA, "Proposal for a Universal EME Moonbounce Window," *Eimac Amateur Service Note 49-3: More on the Moonbounce Universal Window for 144 MHz*, Varian Eimac, Inc., 301 Industrial Way, San Carlos, California 94070.
14. Robert I. Sutherland, W6PO, "Recommendations for Moonbounce Universal Window," *Eimac Amateur Service Note 49-12: Additional Moonbounce Operating Aids*, Varian Eimac, Inc., 301 Industrial Way, San Carlos, California 94070.
15. The Crawford Hill VHF Club W2NFA, "Polarization Standardization for 1296 mc EME," *Technical Report* 1, May, 1968 (see technical notes available, above).
16. Ko, "The Distribution of Cosmic Radio Background Radiation," *Proceedings of the IRE*, January, 1958, page 208.
17. Radio Sky Maps, *Eimac Amateur Service Note 49-25*.
18. C. R. Somerlock, W3WCP, "Sky Temperature Behind the Moon," *QST*, October, 1964, page 38.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

BY0AA revisited

There it is! The QSL card from BY0AA – the station located in the far western province of China, an area that had been void of Amateur Radio activity until now. But where is the town where BY0AA is located? *Wulumuqi* wasn't even on the large wall map of China a friend of mine brought back recently from Peking!

My good friend Ned Jacoby, NG6W, solved the riddle with the aid of the large *Times Atlas of the World*, which explained the variations in spelling Chinese place names. According to that source, the old English Conventional spelling had gone through various convolutions, to be followed by the Wade-Giles translations of place names, which had in turn given way to the newer Pinyin spelling. In the English Conventional system, the name of BY0AA's town was spelled *Urumchi*; in the Wade-Giles system, it was spelled *Wulumuchi*; in the Pinyin system, it's *Urumqui*. BY0AA's QSL card, on the other hand, spells it *Wulumuqi*.

In passing, NG6W pointed out that what we knew as Sinkiang Province is now *Xinjiang Uygur Zizhiqu*. Tibet is now *Xizang Zihiqu!* Lhasa seems to have remained Lhasa. Is it all clear now? (NG6W also suggests that when the pile-ups on BY0AA get too huge, you can always direct-dial them on the telephone via a satellite link!)

do you have AMI?

More and more Amateurs are having problems with AMI (Answering Machine Interference). What next? Some of these little demons seem to have rf sensitivity comparable to that of a good communications receiver. Luckily, the machine I have seems to be rf-proof. But my next-door neighbor has one that turned into a public address system every time I went on the air! The usual cures of wrapping the line cord around a ferrite toroid and placing a telephone type Z-100 filter in the phone line didn't make any difference in the level of interference.

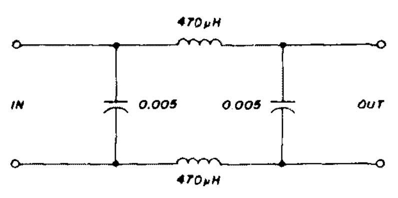


fig. 1. Simple line filter that will work with the telephone or the answering machine.

Not wishing to dig into my neighbor's answering machine, I enjoyed the luxury of indecision until an Amateur friend who had gone through this ordeal a few months earlier came up with a solution that worked for me. His opinion was that the phone company's Z-100 filter was designed mainly to filter out nearby broadcast stations and was therefore relatively ineffective at 14 MHz. He suggested wrapping the power cord of the answering machine around a "lossy" ferrite rod* and then placing a simple rf filter in the answering machine at the point where the telephone line entered the machine (see **fig. 1**). I had no option but to dig into the machine and insert the filter, which turned out to be a simple task. The gamble was worth it. The combination of a lossy line filter for the power cord and the little network filter in the phone line did the job. Keep this scheme in mind if you're unlucky enough to have AMI.

the "computerized" Yagi beam antenna

Great advances in Yagi antenna design have been accomplished in the last decade, thanks to the versatility of the computer. A number of programs for antennas such as the W2PV design and others have been generated; all seem to have been derived from an original program done by I.L. Morris for a PhD thesis at Harvard in 1965. The resulting offspring yield good Yagi

*The ferrite rod measures 7.5 inches long by 0.5 inches in diameter; manufactured by Amidon (No. R33-050-0750), with $\mu = 800$ (type 33 material).

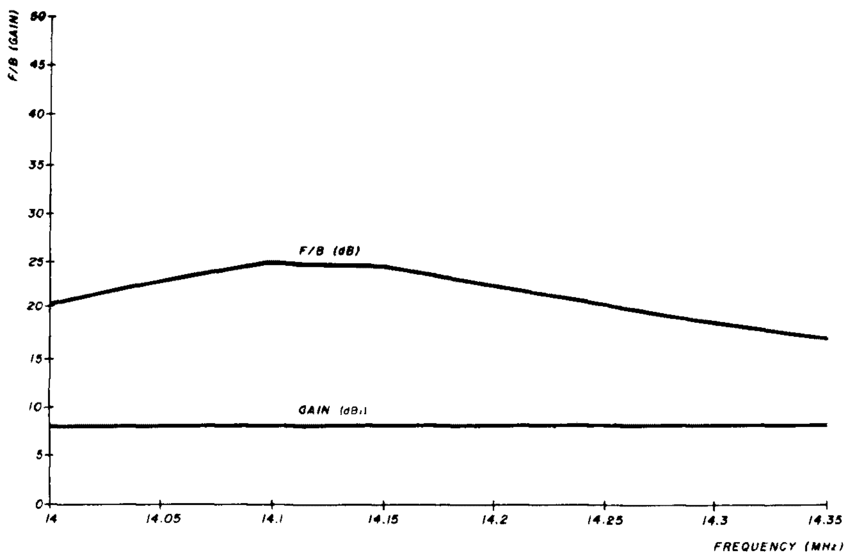


fig. 2. Hy-Gain 204BA four-element 14-MHz Yagi.

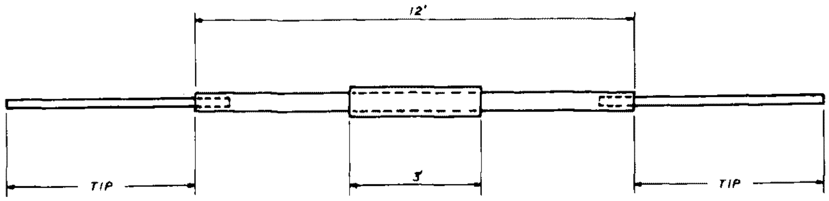


fig. 3. 20-meter Yagi element construction details and dimensions (design frequency = 14.2 MHz).

Table 1. Element dimensions for 20-meter Yagi (design frequency = 14.2 MHz). Construction details are illustrated in fig. 3.

Element	Tip lengths	Spacing
Ref	136.4 inches (346.46 cm)	122.9 inches (312.17 cm)
DE	126.9 inches (322.33 cm)	88.8 inches (225.55 cm)
D1	116.7 inches (296.42 cm)	95.6 inches (242.82 cm)
D2	112.6 inches (286.00 cm)	

data — but unfortunately, all initial conditions don't always converge to the same antenna! The taper data provided by W2PV brought these programs into greater uniformity.

Wayne Hillenbrand, N2FB, working with others, has come up with some computer-aided antenna designs that provide good gain and excellent front-to-back ratio. The data was presented at the 1986 Dayton Hamvention.

The first N2FB design involves a four-element, 14-MHz beam derived from a Hy-Gain 204BA. The gain and front-to-back ratio of the revised antenna are shown in **fig. 2**. Construction details are provided in **fig. 3**; dimensions are given in **table 1**. Each element is made up of a 3-foot length of 1.25-inch diameter sleeve which is slipped over a 12-foot length of 1.125-inch diameter tubing. The tip sections are made of 12-foot lengths of 1-inch diameter tubing.

The driven element appears to be shorter than normal, and this is correct. The length shown provides better SWR bandwidth across the entire band, but doesn't change the antenna pattern.

Details for a modification of the Hy-Gain 205BA-S are provided in **table 2** (see **fig. 3** for element assembly details). Antenna gain remains substantially the same as with the original dimensions, but the front-to-back ratio at the design frequency rises from about 15 dB to nearly 35 dB. Minimum front-to-back ratio (at the band edges) is better than 21 dB with the revised dimensions.

Data for an optimized six-element, 14-MHz beam is shown in **table 3**. The boom length is 54 feet; the boom is made of heavy-wall aluminum tubing measuring 3 inches O.D. All elements are insulated from the boom with a plastic plate. The front-to-back ratio is better than 26 dB across the band.

All beams employ a gamma match feed system. A 4-foot rod is used, with some RG-8/U center conductor fed into the tube for the capacitance adjustment. The end of the tube is crimped to keep water out.

Wayne tells me that 10-meter versions of these antennas have been built by simply scaling down the dimensions. The boom length is slightly altered to allow the use of 12-foot lengths of standard 2-inch diameter industrial tubing. Dimensions for these antennas are given in **table 4** and **table 5**; construction details are shown in **fig. 4**.

Wayne makes the interesting observation that if the driven element is removed, the remaining elements are almost equally spaced. Equal spacing of all parasitic elements produces a high front-to-back ratio, but only for a narrow bandwidth. Wayne is working on a program that compares a Yagi to an LC filter. With that, he expects he'll be able to design for very high Q and narrow bandwidth or lower Q (i.e., poorer front-to-back ratio) but wider bandwidth.

Obviously, great advances are being made in understanding the operation of the Yagi antenna, and it's now possible to custom-design a Yagi for a particular degree of gain, bandwidth, or front-to-back ratio. This demolishes the old W6SAI theory of Yagi design: "Cut the director short, the reflector long, and let 'er rip!"

a toggle-switch box for changing antennas

Use toggle switches for changing antennas? Cliff Klinert, WB6BIH, has tried it at the 100-watt level in the hf region and reports that it works well. He's taken a small aluminum box and mounted two coax receptacles on it, plus four DPDT center-off toggle switches on the face of the box (see **fig. 5**). With this arrangement, he can hook either his transmitter or receiver to any one of four antennas. The box can also be used with two transceivers.

A less obvious use of the "toggle box" is to connect two or more antennas in parallel. Cliff says that his 20-meter Yagi and his 80-meter vertical antenna, when switched in parallel, provide a low enough value of SWR to work well on 15 meters! He's found that for general coverage listening, some combination is always optimum for any frequency.

The center-off switch was chosen so that two radios can be used with minimum danger of transmitting into a receiver. To prevent confusion, all switches should be clearly labeled. The only danger is the possibility of accidentally transmitting when all toggle switches are in the center-off position, which would make any transmitter very unhappy.

75-80 meter helical antenna

Bob Walton, W6CYL, sent me information about this interesting antenna, which was developed by Gene Koenig, W6HVR. The simplified version of his design, shown in **fig. 6**, requires a space of about 40 feet.

The helix is wound from a 110-foot length of No. 15 copper-enamel (or formvar) wire. It's close-wound on a 3/16-inch diameter aluminum rod used as a temporary form.

If you don't have access to a coil-winding machine but know how to operate a lathe, you can do the job that way. You'll need an assistant to track the wire so that it doesn't kink or snarl. Once the coil is wound, the hard part of the job is over.

The helix is supported on a heavy-

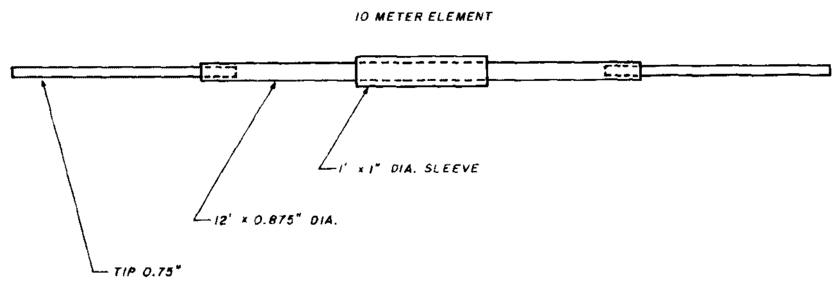


fig. 4. Optimized 28-MHz Yagi's individual element assembly.

Table 2. Dimensions of modified 14-MHz Hy-Gain Yagi (No. 205BA). See fig. 3 for assembly details.

Element	Half-length (inches)	Spacing (inches)
Reflector	213.23	65.2
Driven Element	198.68	64.8
Director 1	198.21	124.1
Director 2	188.55	153.7
Director 3	181.52	

Table 3. Dimensions of six-element, 14-MHz optimized Yagi on 0.75 wavelength boom (maximum gain = 10.71 dBi). See fig. 3 for construction details.

Element	Tip	Spacing
Reflector	139 inches (353 cm)	86.4 inches (219.5 cm)
Driven Element	124.5 inches (316.2 cm)	77.7 inches (197.4 cm)
Director 1	126.6 inches (321.6 cm)	157.5 inches (400 cm)
Director 2	121.9 inches (309.6 cm)	142.9 inches (362.9 cm)
Director 3	121.9 inches (309.6 cm)	142.9 inches (362.9 cm)
Director 4	113.5 inches (288.3 cm)	

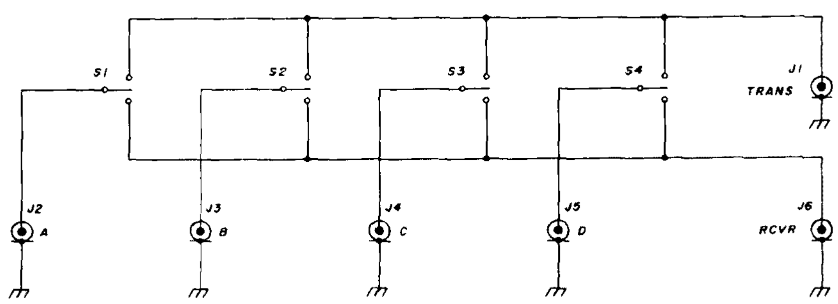


fig. 5. Toggle switch antenna box schematic.

Table 4. Optimized 28-MHz Yagi: six-element, 24-foot boom, 10-meter Yagi dimensions (see fig. 4 for construction details).

Element	Tip lengths	Spacing
Ref	33.48 inches	35.19 inches
DE	26.25 inches	35.86 inches
D1	27.32 inches	75.75 inches
D2	25.19 inches	68.43 inches
D3	24.95 inches	86.77 inches
D4	20.77 inches	

Table 5. Optimized 28-MHz Yagi: four-element, 12-foot boom, 10-meter Yagi dimensions (see fig. 4 for construction details).

Element	Tip lengths	Spacing
Ref	31.70 inches	57.55 inches
DE	26.25 inches	40.38 inches
D1	21.84 inches	43.82 inches
D2	19.82 inches	

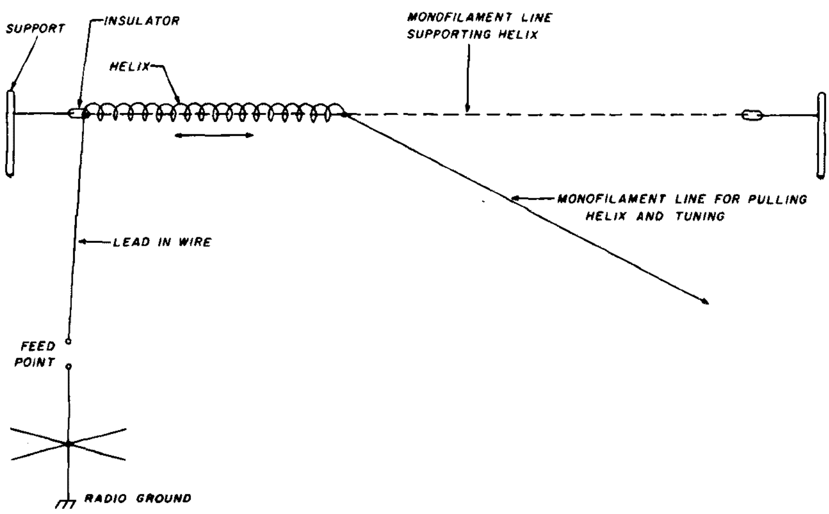


fig. 6. Simplified version of W6HVR 80-meter tunable helix antenna.

duty monofilament fishing line — the type used for ocean fishing. The helix is carefully laid out on the ground, still close-wound. A length of the nylon monofilament line is fished through the center of the helix, using an aluminum welding rod as a guide or needle. One end of the nylon line is then run to an insulator. A second length of nylon line is attached to the far end of the helix to permit expansion and compression of the coil. This line is left dangling, and the far end of the assembly is hoisted to the top of the support structure. The opposite end of the helix is attached to the feed wire. The nylon center rope is then used to pull the helix into the final position.

As an end-fed antenna, it requires a good ground system. A ground rod, plus quarter-wave radials laid on the ground, are recommended.

The antenna is capable of operation across the 80-meter band. To resonate the antenna, the helix is pulled out with the nylon cord. Bob recommends the use of a noise bridge and the station receiver for the initial adjustments. The antenna can be then be fine-tuned with the aid of an SWR meter and a little transmitter power.

Although this antenna is only about 40 feet long, its bandwidth response is quite good. It's possible to bring the nylon cord back to the operating room and tune the antenna to any portion of the 80-meter band by adjusting tension on the cord. With the use of a tuner, it will operate on the higher frequency Amateur bands.

new EME directories

A new supply of the popular "144 MHz EME Directory" has been printed. This lists many of the moonbounce stations and operators, giving the name, call, address, phone number (where applicable), and equipment. To obtain your copy, send five first-class stamps (or five IRCs) to me at EIMAC, 301 Industrial Way, San Carlos, California 94070.

ham radio

designing trap antennas: a new approach

Symmetrical design increases gain and directivity

Most Amateurs don't realize that the original design of a trap antenna[1,2,3,4] represents just one particular case, and is not the best possible choice of the many designs available. According to the references, a dipole designed to resonate at two frequencies, f1 and f2, contains parallel RLC circuits — or *traps* — that are resonant at the upper frequency, f2, and physically separated by a half wavelength (at f2). This approach I call the "classic" design. At f2 these circuits offer a very high impedance and, in effect, disconnect the outer portions of the antenna. The inner portion acts as a half-wave dipole. With the total antenna length made equal to one half wavelength at the lower design frequency, f1, the antenna would resonate at this frequency if the traps presented a short circuit. In practice, however, the traps introduce an inductive reactance at all frequencies lower than f2. To compensate, the total length of the antenna is slightly shortened in order to be resonant at f1.

Treatments of this subject in reference books usually ignore other existing designs and imply incorrectly that this description applies to all trapped antennas.

Extending this design approach to three bands (10, 15, and 20 meters) would require the two sets of traps to resonate at 21 and 28 MHz and be separated by approximately 3 feet (on each half-dipole element). Some of the first commercially manufactured triband antennas actually did use separated traps, but those generally available today have such pairs of traps built into a single assembly.

A vertical trap antenna, just slightly longer than a quarter wavelength at the upper frequency f2, was discussed in an earlier article; the principle upon which that antenna was based can be applied to dipoles as well.[5] In this case, the trap is placed at the base of the antenna and its parameters are selected to produce the correct inductive reactance for resonance at the lower frequency f1. At f2 the antenna is slightly longer than a quarter wavelength, and the trap provides the necessary *capacitive* reactance for resonance to be achieved.

To lower the resonant frequency of a fixed-length dipole, inductance must be added. Conversely, capacitance must be added to raise its frequency. A parallel RLC circuit can provide the required reactances at f1 and f2. (A series RLC circuit, which has a capacitive reactance at low frequencies and inductive reactance at high frequencies, cannot be used in this application.)

There's wide variation in the positioning of the traps, which affects the properties of the antenna (directivity, bandwidth, efficiency, and trap resonant frequencies). Mathematically speaking, the design of a trapped antenna is over-determined since there are *four* parameters to be adjusted in order to meet the *two* resonance conditions at f1 and f2: total length; trap position; trap resonant frequency, f0 (when removed from the antenna) and the value of the capacitance, C.

Without further information, it's impossible to say how these parameters are to be selected in order to obtain the best performance. The classic design isn't optimum because the outer portions of the dipole have little current at the upper frequency, f2. A design that causes a significant current to flow in these outer portions can improve directivity.

In addition, minimum loss reactances should be used. The capacitive loading required by a single-band antenna longer than a half wavelength can usually be supplied with negligible loss. However, inductive loading required for a single-band short dipole usually adds

By Yardley Beers, WØJF, 740 Willowbrook Road, Boulder, Colorado 80302

some losses. With a two-band trap antenna, the losses are usually greater at both frequencies than if single-band loading is used. Because losses tend to be greater if the trap resonance is near one of the operating frequencies, I'll discuss a design in which f0 is as far removed from the operating frequencies, f1 and f2, as possible, and in which the traps have equal impedances at these two frequencies. For this to occur, the trap resonant frequency, f0, must be equal to the geometrical average of f1 and f2 — that is, equal to the square root of their product. The reactances at the two design frequencies are equal in magnitude but different in sign, and the resistances are equal. I call this approach the *"symmetrical"* design.

a dual-band antenna

To illustrate this principle, two separate two-band trap dipoles were built; the first for 18.1 and 24.9 MHz, and the second for the 14- and 21-MHz bands. Actually, I have built two of the former; the first had minimum SWRs of 1.5 in the 18.1-MHz band and 1.4 in the 24.9-MHz band. After I had dismantled it, I improved my computer programs for designing these antennas and built the 14/21-MHz antenna, with which I obtained minimum SWRs of 1.1 on both bands. I reworked the calculations for the 18.1/24.9-MHz antenna and got slightly different values. I decided that although the original antenna was still useful, I hadn't *trimmed* it to best advantage. I built the second antenna with significantly different dimensions and, as shown in **fig. 1**, it has minimum SWR of 1.1 on both bands.

18.1/24.9-MHz dual-band antenna

Both antennas were developed for design frequencies of 18.118 and 24.94 MHz with a trap design frequency of 21.257 MHz, using nominal trap capacitances of 50 pF. After the second version of the dual-bander was built, the trap capacitances were measured at 51.6 pF. The trap resonances measured, on the average, 21.27 MHz. The inductors consisted of 13 turns of No. 18 plastic-coated wire wound on 1/2-inch diameter plastic rod. Since I operate at low power (about 100 watts) I was able to use No. 18 wire, but I advise those readers who intend to operate at higher power to build inductors with heavier wire. I didn't measure the *Q*s of the coils, but I assume that 200 is a reasonable value. (Resonance is independent of the *Q*.) Using these values and **eqns. 8, 10,** and **11** (see **appendix 1**), I found the magnitude of the reactances and the resistances to be 449 and 7.0 ohms, respectively.

The total antenna length is 20.0 feet. The traps are 13.8 feet apart, symmetrically placed about the center feedpoint. The earlier antenna, with similar traps, had dimensions of 20.7 feet (length) and 15.3 feet (trap separation). For comparison, the (unloaded) lengths of half-wave dipoles for these design frequencies, as given by **eqn. 6** (see **appendix 1**), are, respectively, 25.9 feet and 18.8 feet. The wire is No. 14 gauge. Standing wave measurements relative to a 50-ohm transmission line, with the antenna 20 feet above ground, are shown in **fig. 1**. The measurements take line losses into account.

Before building the second antenna, I followed the mathematical procedure discussed in **appendix 2**, which gave the following results: for S1 (the distance from the center feedpoint to one trap), 6.90 feet; for S2 (the distance from a trap to the end), 3.88 feet. With these dimensions, the SWR pattern at 24.94 MHz wasn't very different from that shown in **fig. 1**, but the f1 SWR minimum of 1.2 was at 17.4 MHz, about 5 percent too low in frequency. I tried trimming both S1 and S2. Finally I retained the original value of S1, but I reduced S2 by 0.8 feet (9.5 inches) for a final value of 3.08 feet. These dimensions apply to **fig. 1**.

Moxon gives a method for estimating the efficiency of trapped antennas.[6] It's necessary to *measure or assume* values for the radiation resistance. The minimum SWR at both frequencies is 1.1, which implies that the total resistance at the drivepoint is between the limits 50/1.1 = 45.5 ohms and 50 x 1.1 = 55 ohms. Because the radiation resistance is larger for dipoles greater than one half wavelength and less for those less than one half wavelength, I assumed the lower (resistance) value for f1 and the upper one for f2.

The power radiated is the current at the center multiplied by the square of the current at the center. The power lost in the traps is their resistance multiplied by the square of the current at the traps, which is smaller than at the center. The total resistances of the traps is actually 14 ohms, but a calculation shows that the losses are as though the trap resistances were at the center and had the values of 5.8 and 2.0 ohms, respectively, at f_1 and f_2. After subtracting off these transformed loss resistances, I obtain estimates for the radiation resistances at the two frequencies as 45 − 5.8 = 39.2 and 55 − 2.0 = 53 ohms, respectively. The efficiencies are then respectively 39.2/45 = 87% and 53/55 = 96%.

However, since the radiation resistance of a half-wave dipole is about 72 ohms, one would expect the radiation resistances to be slightly higher than the estimates given above; consequently, working with the same trap resistances, efficiency should actually be higher.

15/20-meter dual-band antenna

The design frequencies for this antenna are, respectively, f1 = 14.15, f2 = 21.2, and f0 = 17.32 MHz. The trap capacitors have measured values of 52 pF, on the average. The inductors are seven and a half

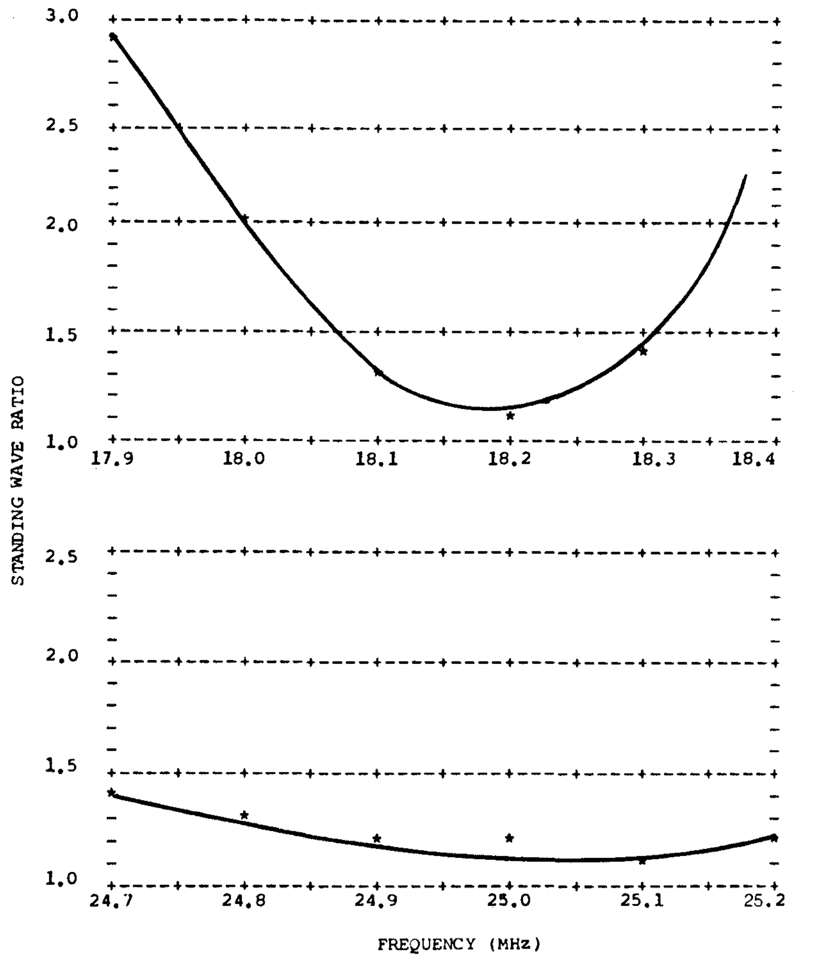


fig. 1. SWR vs. frequency for trapped dipole for use in 18.068-18.168 MHz and 24.890-24.990 MHz bands. The antenna is 20 feet, 10 inches long and has traps placed 15 feet, 2 inches apart, equidistant from the center feedpoint. The traps use 50-pF capacitors and are self-resonant at 21.2 MHz.

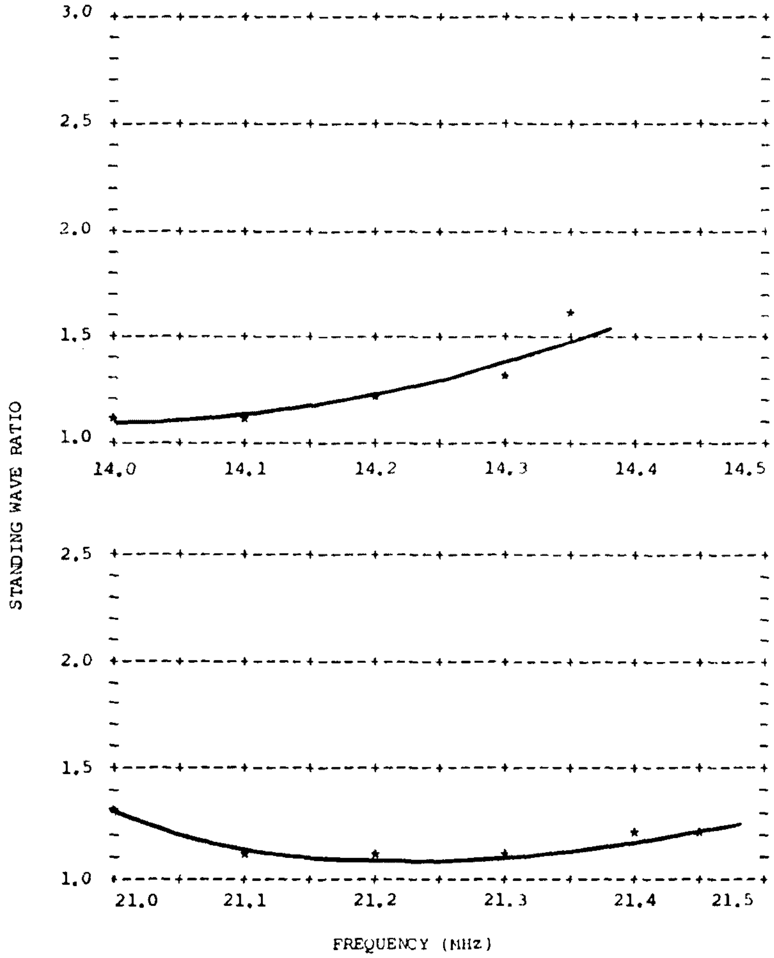


fig. 2. Standing wave ratio vs. frequency for a trapped dipole for use in the 14- and 21-MHz bands. The antenna is 24 feet, 7 inches long and has traps placed 14 feet, 5 inches apart, equidistant from the center. The traps use 50-pF capacitors and are self-resonant at 17.4 MHz.

turns of No. 18 plastic-coated wire on 1-inch plastic pill bottles. The wire spacing was varied to adjust the resonant frequencies of the traps. During coil construction, the half turn was left slack for fine tuning. The average measured resonant frequency was 17.41 MHz. The wire used in the antenna is No. 12 gauge.

Appendix 2 provides a detailed discussion of calculations which suggested the initial dimensions S1 = 7.69 feet and S2 = 5.41 feet. After I trimmed them experimentally to S1 = 7.36 feet and S2 = 5.24 feet, I obtained the standing wave pattern shown in **fig. 2**.

As the length of a loaded dipole, measured in wavelengths, increases, the bandwidth increases. Although a wider bandwidth is expected at f2 than at f1, I can't explan why bandwidths I've observed at f2 are very much wider than those at f1. These different bandwidths showed considerable sensitivity to changes in length while trimming; in each of the three cases I've dealt with, the standing wave pattern at f2 has changed hardly at all when I changed the dimensions, but a change of only a few inches made a significant change in the f1 resonance frequency. It's likely that the f1 resonance is very susceptible to changes in antenna location.

theory of the symmetrical design

The selection of a trap antenna's dimensions can be made almost entirely by experiment. The only mathematics one needs to build a two-band antenna using the symmetrical design is to calculate f0 by taking the square root of the product of f1 and f2. After installing the traps and adjusting the antenna length and trap location, a working antenna is produced. The mathematical details can usually save the designer some time by providing at least a "starting point."

In designing a trap antenna, the following conditions must be satisfied: it must resonate at f1; it must resonate at f2; the trap resonant frequency must be the geometric average of f1 and f2. The trap resistances at f1 and f2 are equal, and the reactances are equal in magnitude but opposite in sign. Arbitrarily, I chose 50 pF as a convenient value for the trap capacitances. (The effect of using other values is also considered.) The required value of the trap inductances, L, can then be determined by **eqn. 7**.

Most of the necessary formulas are listed in **appendix 1**, with detailed examples provided in **appendix 2**. The condition for resonance is that the total reactance as referred to any point on the antenna is zero. It is axiomatic that if the total reactance at *any* one point is zero, then it is zero at all other points. For convenience, I chose the trap location as a reference point and considered only half the dipole at a time.

The antenna and the ground can be thought of as forming a transmission line. Although the center is connected to the feedline, I assume that its input impedance, as viewed at the location of the trap, is the same (positive) reactance, X1, as it would be if the center were connected to ground. Calculate this with **eqn. 15**. Similarly, I consider the part between the trap and the end as a section of open-circuited transmission. Its impedance is given by the (negative) reactance, X2, in **eqn. 17**.

If S1, the distance from the center to the trap, and if S2, the distance from the trap to the open end, are a quarter wavelength long, then X1 + X2 = 0, *independent of the value of S1*. This configuration is well known as a resonator.

For resonance using arbitrary lengths of S1 and S2, it's necessary to introduce a reactance X such that:

$$X + X1 + X2 = 0 \qquad (1)$$

Various values of S1 and S2 are tried until the equation is satisfied at both f1 and f2. (See **appendix 2**.)

As a simplification, a characteristic impedance of 575 ohms was calculated for a transmission line consisting of a horizontal 12-gauge wire parallel to and 20 feet above a perfectly conducting groundplane (**eqn. 14**). Though good for a transmission line, this formula neglects the effect of radiation, and, of course, radiation is the primary purpose of the antenna.

The calculation of characteristic impedances of radiating antennas is more complicated.[7]

parallel RLC circuit properties

A complete understanding of the design of trap antennas requires a knowledge of parallel RLC circuits. Graphs of impedance, series resistance, and series reactance are shown as a function of frequency *f* in **fig. 3**. These normalized curves require that quantities plotted on the vertical scale be multiplied by the value of *R*, and the frequency shift measured from the resonant frequency be given in units of *D*, where

$$D = f0/2Q \qquad (2)$$

Losses in the inductor and capacitor are represented by a resistance, *R*, where:

$$R = \frac{500{,}000Q}{\pi Cf0} \text{ ohms} \qquad (3)$$

and *C* is the capacitance in picofarads, and *f0* is the resonant frequency in MHz.

To apply these ideas to the traps in the 18.1/24.9-MHz antenna, *f0* = 21.257 MHz, *C* = 51.6 pF, *R* = 29,002 ohms, and *D* = 0.053 MHz (53 kHz). The reactance has small positive values at low frequencies and increases to a maximum of 0.5 R = 14,501 ohms at a normalized value of − 1 (21.204 MHz), after which it decreases to zero at resonance. Then it decreases to a negative maximum − 0.5 R = − 14,001 ohms, at + 1 (21.310 MHz) and approaches zero at very large frequencies.

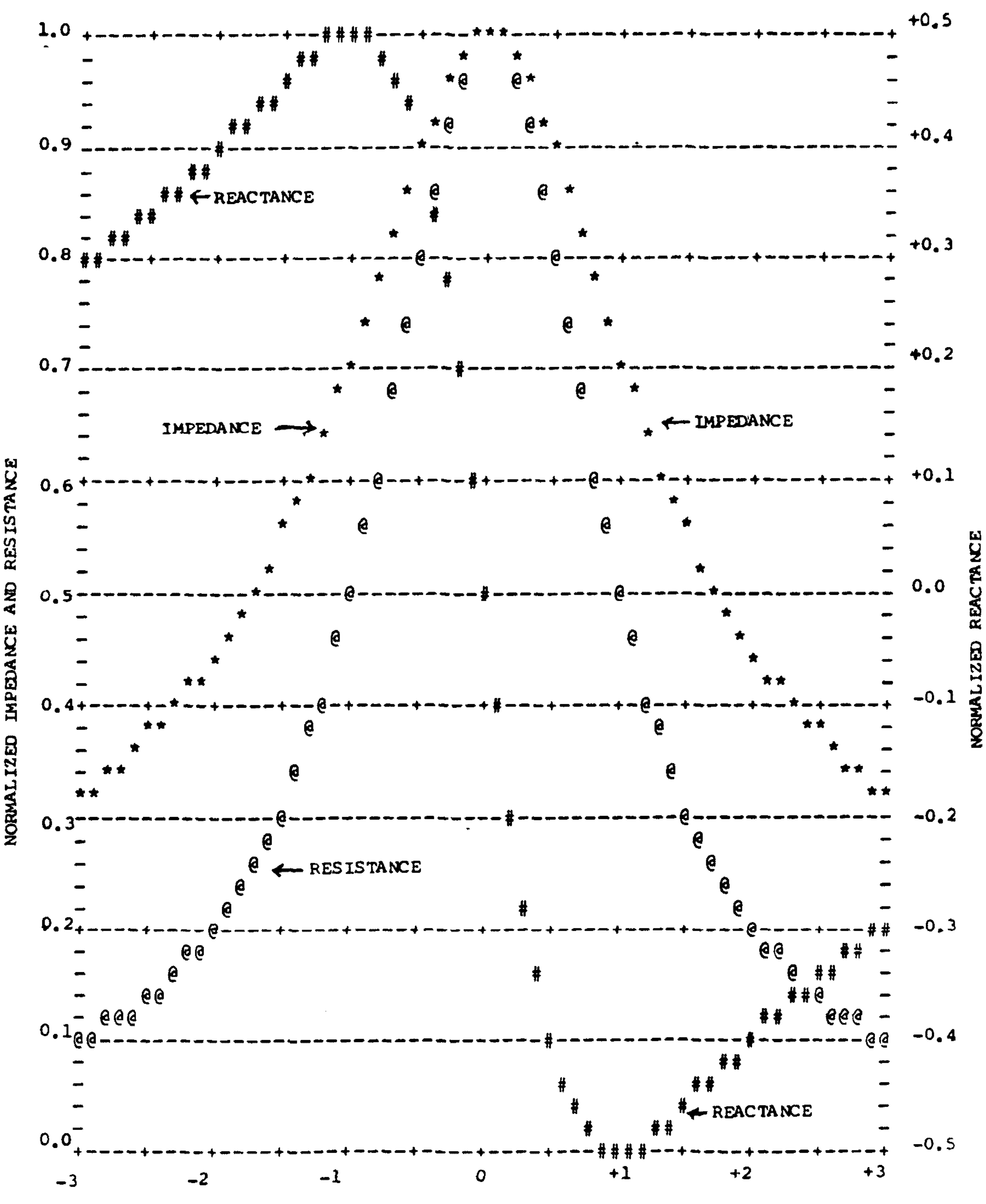


fig. 3. Normalized impedance, resistance, and reactance of a *parallel RLC* circuit as a function of frequency. The frequency is given in terms of the shift from the resonant frequency f0 in units of $\frac{f0}{(2Q)}$. When these curves are applied to an actual circuit the quantities plotted vertically are multiplied by the shunt impedence of the circuit at resonance which is $\frac{1}{2\pi\ f0C}$.

The design frequencies, f1 and f2, correspond *respectively to* -70.6 *and* $+58.4$, *and lie very far off* the graph in **fig. 3**. The values of the impedances, resistances, and reactances cannot be obtained from the graph and must be calculated by formulas such as those shown in **appendix 1**. The reactances, as stated previously, *are* ± 449 ohms and the resistances are 7.0 ohms. Consequently, the circuit can be considered as a low-loss reactance.

Since the reactance goes through zero at resonance, there are two other frequencies — very close (about *10 kHz)* — at which the *desired reactance* of ± 449 ohms can be obtained. There the resistance is very close to its maximum value. Such a reactance would hardly be considered low-loss! This is the situation encountered when such a circuit is used as a trap at f2 in the classical design. In such a situation the RLC circuit becomes a "trap" in another sense of the word: as an absorber of power.

The curves shown in **fig. 3** assume that *Q* is at least 10 and preferably much larger, as is likely to be the case in practice. The errors resulting from this assumption are then negligible. This assumption simplifies the math. When *Q* is small, it is necessary to draw individual curves. **Equations 8, 9, 10,** and **11** don't have this limitation.

Another assumption is that the losses in the circuit are represented by a resistor, R, whose value is given by **eqn. 3**, and that its value is independent of frequency. Strictly speaking, this assumption is unrealistic. Most of the losses are in the inductor, and they depend upon frequency in a complicated way because of skin effect and distributed capacitance.

For physical reasons, air (dielectric) capacitors often aren't practical to use in antenna traps — but they are low-loss. The losses in solid dielectric capacitors are generally lower than those in the *inductors,* but they (the losses) mustn't be overlooked. While an air-core inductor has the shape to dissipate heat, a solid-state capacitor does not; a small amount of power dissipated in it causes its temperature to rise and its capacitance to change. If the effect is large, the antenna is detuned when the power level is raised. Thus, a solid-state capacitor has a current limitation as well as a voltage limitation. Usually one that has a high voltage rating can also pass a lot of current, but this isn't always true. Capacitors with thin pigtails, even with high voltage ratings, must be avoided. Sometimes it's necessary to use more than one capacitor in series or parallel to get sufficient current carrying capability.

conclusion

The main purpose of this article is to review the principles of design of trapped antennas and to show that there are alternative designs that are superior to the classic one. I've illustrated the principles by showing the design of practical antennas for the 18.1- and 24.9-MHz bands, and for the 14- and 21-MHz bands.

A central point of the discussion is that the operating and trap frequencies should not coincide. **Equation 12** shows that with far-off resonance the series resistance decreases with the square of the difference between the operating and trap resonant frequencies. A further argument for keeping the trap resonant frequency remote from the operating frequency is the fact that the same RLC circuits used in the 18.1/24.9-MHz antenna could be used as traps in a 14/21-MHz *dual-band* antenna of classic design. The total trap resistance at the new f2 (21 MHz) is about 58,000 ohms. In considering such an antenna, Moxon[6] estimates that the radiation resistance, when transformed to the trap location, is about 32,000 ohms. Therefore, the efficiency is about (32/60) = 53 *percent,* whereas the efficiency with the symmetrical design at f2 = 24.94 MHz is 96 percent. Furthermore, with the symmetrical design there is significant current in the outer portions, and the directivity is greater. Therefore, at the upper frequency, f2, there is a significant advantage of the symmetrical over the classic design. With the classic design, the lower frequency, **f1**, is further from resonance than with the symmetrical design, and therefore the loss resistance is lower and the efficiency is *higher.* With the symmetrical design, *it* is already very good — 87 percent — so this advantage is not important.

I haven't tried to optimize the value of the trap capacitances. **Equation 13** shows that the resistances of the traps' far-off resonance are inversely proportional to the product of the capacitance and the *Q* of the traps. With the present values of 50 pF and a *Q* of 200, they're about the largest acceptable. If the capacitances were lowered to 25 pF, the resistances would be double and would cause a significant reduction in efficiency at both operating frequencies. If they were made 100 pF, there would be an insignificant improvement in the efficiency.

The principle of symmetrical design should be applicable to a 14/21/28-MHz triband dipole. The traps should be resonant in the vicinity of 17 MHz and 24 MHz, respectively. Efficiency and directivity would be greater. However, there would be a problem in extending the design to many bands; the radiation resistance would be different on the lowest and highest frequency bands, and an elaborate impedance matching network would be required to get a good match to the transmission line for all bands.

This article has dealt only with a single dipole. This approach can be applied to multi-element antennas with both driven and parasitic elements.

acknowledgments

I wish to thank Les Moxon, G6XN, Francis M.

Dukat, K6NL, and Oswald G. Villard, Jr., W6QYT, for their valuable suggestions.

appendix 1

basic equations

The formulas have been used for calculations discussed in the text. The wavelength

$$\lambda = 299.8/f \text{ in meters} \tag{4}$$

$$= 983.6/f \text{ in feet, with the frequency } f \text{ in MHz.} \tag{5}$$

The length of a half-wave dipole is

$$G = 468/f \text{ in feet.} \tag{6}$$

Equation 6 gives a length which is 95 percent of a half wavelength as given by **eqn. 5** because of corrections for end effects. This simplification valid for hf wire antennas depends on the ratio of conductor diameter to wavelength. At VHF, where the ratio is usually smaller, the correction is larger.

The inductance L (in μH) required to resonate with a capacitor C (in pF) at a frequency f0 (in MHz) is

$$L = \frac{1}{4\pi^2 C (f_0)^2} \tag{7}$$

It is convenient to define a new quantity, t

$$t = Q \cdot \frac{f^2 - f_0^2}{f \cdot f_0} \tag{8}$$

where $f0$ is the resonant frequency of the RLC circuit and f is any arbitrary frequency. The impedance is given by

$$Z = \frac{R}{\sqrt{1 + t^2}} \tag{9}$$

The series resistance is given by

$$R_s = \frac{R}{1 + t^2} \tag{10}$$

and the reactance is given by

$$X_s = \frac{R\,t}{1 + t^2} \tag{11}$$

To understand the behavior of traps far from resonance, it is desirable to derive approximate expressions for the resistance and reactance.

$$R_s = \frac{f_0}{8\pi\, CQ\, (f - f_0)^2} \tag{12}$$

The resistance is inversely proportional to the square of the frequency shift.

The reactance far-off resonance is given approximately by

$$X_s = \frac{1}{4\pi C\,(f_0 - f)} \tag{13}$$

Because reactance far from resonance is independent of Q, it isn't necessary to have values of the Qs of the traps to make calculations involving resonance conditions.

A transmission line consisting of a wire of diameter d parallel to and at a distance H from a conducting plane has a characteristic impedance of

$$Z_0 = 138\, LOG_{10}\, (4H/d) \text{ ohms} \tag{14}$$

H and d can be in any similar units.

A section of lossless transmission line of length S1 short-circuited at the far end has an input reactance of

$$X_1 = Z_0\, TAN\, A \tag{15}$$

where

$$A = \frac{360 \cdot S1}{\lambda} \tag{16}$$

A is the length S1 expressed as an angle in degrees.

A section of transmission line of length S2 open-circuited at the far end has an input reactance of

$$X_2 = \frac{-Z_0}{TAN\, B} \tag{17}$$

where

$$B = \frac{360 \cdot S2}{\lambda} \tag{18}$$

is an angle corresponding to the length S2.

Equation 1 gives the condition for resonance at a single frequency. It is necessary to derive from it an equation giving the condition for resonance at the two frequencies f1 and f2. Note from **eqns. 16** and **18** that angles A and B are inversely proportional to wavelength. Therefore they are, for fixed lengths S1 and S2, proportional to the frequency. Hence, if we now use A and B to denote the angles at the upper frequency f2, at f1 they are reduced by the factor f1/f2. Since the design is based on the assumption that the trap reactances at these two frequencies are equal in magnitude but opposite in sign, it follows from **eqn. 1** that:

$$-TAN\, \frac{Af1}{f2} + \frac{1}{TAN\, \frac{Bf1}{f2}} = TAN\, A - \frac{1}{TAN\, B} \tag{19}$$

The characteristic impedance Z_0 has cancelled out.

This equation cannot be solved exactly. It has to be solved

Table 1. Trial solutions for resonance.

Trial	Angle A (Degrees)	Angle B (Degrees)	Residual U	S1 (feet)	S2 (feet)	Reactance (ohms)
1	65	35	−0.654	—	—	—
2		33	−0.922	—	—	—
3		37	0.412	—	—	—
4		41	+0.0072	—	—	—
5		40.8	−0.012	—	—	—
7		40.9	−0.002	8.38	5.27	569
10	60	47	−0.00014	7.73	6.06	459
16	60.3	46.65	+0.00035	7.77	6.01	465
23	59.7	47.35	−0.00054	7.69	6.10	454

Note: Reactions are trap reactances needed for resonance, positive at F1, negative at F2.

numerically by trial and error. For this purpose it is convenient to define a quantity U, called the residual, as follows:

$$U = TAN\ \frac{Af1}{f2} + TAN\ A - \frac{1}{TAN\ \frac{Bf1}{f2}} - \frac{1}{TAN\ B} \qquad (20)$$

If the left side of eqn. 19 is transposed to the right, the result is identical to the right side of eqn. 20, but on the left is U instead of 0. It is solved by trying values of A and B, which ideally make U equal to zero. In practice it is impossible to obtain zero exactly. The practical method is to choose a value of A and then find two values of B that are close together, one of which gives a small positive value to U and the other of which gives a small negative value to it. Then, one or the other, or some intermediate value can be taken as the desired value of B. This method is illustrated below.

appendix 2

designing a 14/21-MHz antenna

First select the design operating frequencies. In this example f1 = 14.15 MHz and f2 = 21.2 MHz. Next calculate the trap resonance frequency f0 = 17.32 MHz by taking the square root of the product of f1 and f2. As a starting point, assume a value of trap capacitance of 50 pF. **Equation 7** can then be used to calculate the inductance needed for resonance, 1.69 μH. Assuming a Q of 200, eqns. **8**, **10**, and **11** can then be used to calculate the reactance and resistance at the design operating frequencies. These turned out to be $\pm$ 451 and 5.55 ohms, respectively.

By repetitively substituting best length "guesstimates" into eqn. 20 the final correct values for resonance are found. (See **table 1**.) The first guess was for an angular length, A, of 65 degrees and B of 35 degrees, which gave a large residual U of -0.654. Then, using the fixed value A = 65 degrees, I used B = 33 degrees as a second guess to obtain U = -0.922, which of course, is still further from zero. Therefore, it was obvious that it was necessary to increase B rather than to decrease it. B was gradually increased until U had the value +0.0072, which I considered reasonably close to zero. Next, eqns. **5**, **16** and **18** are used to determine distances S1 and S2 in feet and reactance magnitude. In the reactance calculation I assumed a value of 575 ohms for the characteristic impedance. The first value determined for reactance was 569 ohms which is significantly different from the trap reactance 451 ohms. Therefore it was necessary to repeat the process using other values of A.

For the other values of A in **table 1** I have given only the results for the final trial values of B. A reactance of 454 ohms in the last line was considered close enough to the calculated trap reactance of 451 ohms to start building the antenna.

Nevertheless S2 still had to be corrected for end effects. Half-wave wire dipoles, as suggested by eqn. **4**, have physical lengths of 95 percent of the free space half wavelength. I assumed that a similar correction must be made to a trap antenna. In principle, the correction is slightly different at each of the operating frequencies. As a simplifying approximation, I assumed that it is the same as it would be for a half-wave dipole at f0 = 17.32 MHz, which I found to be 0.69 feet. Therefore, I reduced the computed value of S2 from 6.10 feet to 5.41 feet.

The entire calculation, starting with the calculation of $f0$ and ending with the end correction, took less than 20 minutes with the use of the programs I had written for my Commodore 64 computer.* These calculations can also be performed with any hand calculator that features trigonometric functions.

The traps were then built and measured; average resonant frequency was 17.2 MHz. Using the dimensions S1 = 7.69 feet and S2 = 5.41 feet, a minimum SWR of 1.1 occurred at 13.75 MHz and 1.2 at 20.7 MHz. These frequencies are about 3 percent lower than the design ones. This observation suggests that the dimensions should be reduced about 3 percent, or each S1 and each S2 should be shortened by 2 inches. When I made this change, the SWR was 1.2 at 14.0 MHz and 1.3 at 21.0 MHz, and in both bands it increased with frequency with the implication that the minima were at the low edges or outside the low edges. I then removed 2 more inches from each S1. Then, with the final dimensions S1 = 7.36 feet and S2 = 5.24 feet, I obtained the standing wave pattern shown in **fig. 2**.

Thus the final dimensions differed from the calculated ones by only a few percent. In view of the uncertainties that are present, the agreement between theory and experiment is as good or better than can be expected. The biggest uncertainty is the value of the characteristic impedance. The end correction is another. Then there are experimental sources of error due to the length of the leads on the traps and due to the wires wound on the insulators. At the same time, the theoretical calculation provided a useful guide which probably reduced the experimental adjustment by hours. Trial and error can be done much more rapidly by computer than by experimentl

*Copies of these programs are available; send a self-addressed business-sized envelope with two first-class stamps, plus one loose first-class stamp to cover the cost of photocopying.

references

1. Terman[2] gives the following reference as the original work on trapped antennas: Howard K. Morgan, "A Multifrequency Tuned Antenna System," *Electronics*, August, 1940, page 42. (When I looked in this publication, I failed to find this paper there; I have been unable to locate it elsewhere.)
2. F. E. Terman, *Radio Engineers' Handbook*, McGraw-Hill Book Co., New York, 1943, page 854.
3. Chester L. Buchanan, W3DZZ, "Duo Band Antenna," *Radio and Television News*, December, 1950, page 66.
4. Chester L. Buchanan, W3DZZ, "The Multimatch Antenna System," *QST*, March, 1955, page 22.
5. Yardley Beers, "Short Antennas for the Lower Frequencies — Part 1," *QST*, August, 1970, page 26.
6. L. A. Moxon, G6XN, *HF Antennas for All Locations*, Radio Society of Great Britain, London, 1982, page 109.
7. See, for example, S.A. Schelkunoff and H. T. Friis, *Antennas: Theory and Practice*, John Wiley and Sons, New York 1952, section 13.4.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

battery problems: part 2

Last month we discussed NiCd batteries; this month we'll take a look at charging systems for NiCds, as well as lead acid and gel cel batteries.

charging NiCds

There are two basic forms of charger for NiCd batteries: constant-current (CI) and constant-voltage (CV). Regardless of the type, it's important to use a charging current no greater than A-H/10 unless specifically instructed to do so by the battery manufacturer (not the equipment maker, by the way). The A-H/10 rate is one-tenth of the ampere-hour rating. For a 500-mAH AA cell, for example, a 50-mA charging current is used. Similarly, 200 mA should be used for a 2 A-H C cell, and 400 mA for the 4 A-H D cell. (Be careful not to overcharge batteries using other A-H ratings.)

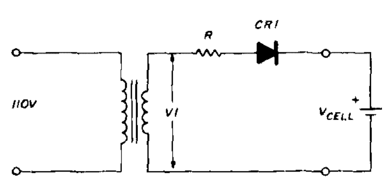


fig. 1. Simple constant-current battery charger.

Figure 1 shows the basic circuit for a low-cost constant current charger of simple design. The transformer secondary voltage should be 2.5 or more times the cell or battery voltage. The resistor in series with the rectifier limits the output current under short-circuit conditions to the A-H/10 charging rate.

Figure 2 shows two electronic CI chargers based on three-terminal IC voltage regulators. The variable circuit shown in **fig. 2A** is based on the LM-317 (up to 1 ampere) and LM-338 (up to 5 amperes). Both circuits require a filtered dc input voltage several volts higher than the battery or cell potential. The actual value isn't critical as long as it's high enough to turn on the circuit (in general, V_{in}) is greater than (V_B + 3 volts). We can adjust the charge current by setting the value of resistor R. For example, for a 400-mA charger for 4 A-H D cells, we would use a resistor value of $1.2/I = 1.2/0.4 =$ 3 ohms. Charging currents down to 10 mA can be accommodated by the circuit shown in **fig. 2A**, so both regular and trickle chargers can be designed.

The circuit shown in **fig. 2B** will charge batteries up to 4 A-H with ter-

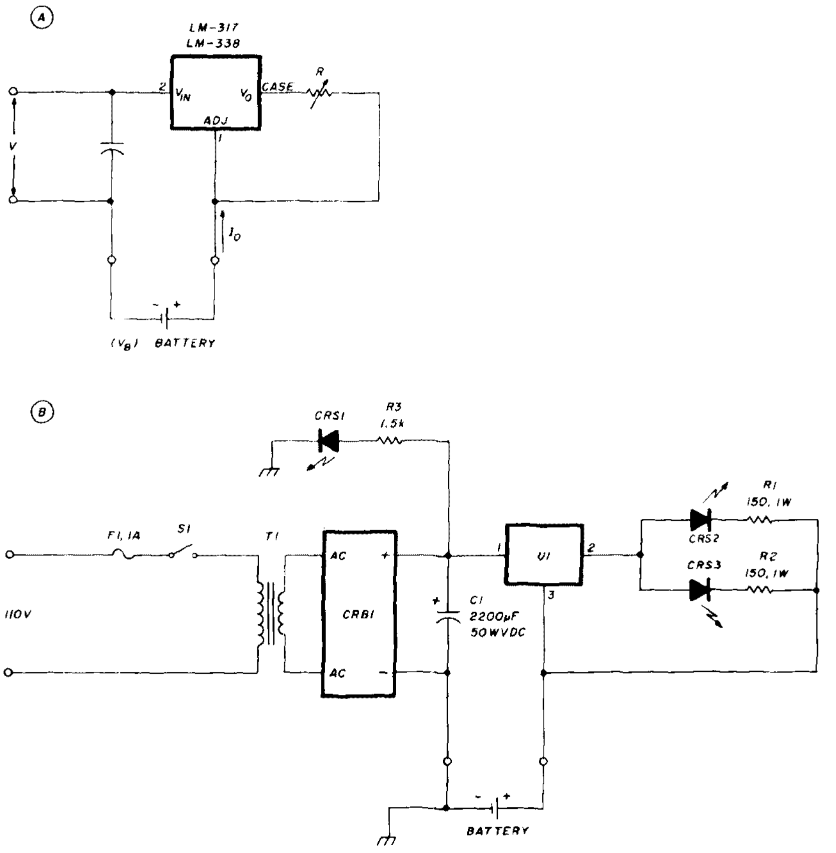


fig. 2. Constant-current chargers: (A) variable voltage charger uses LM-317 or LM-338 regulators; (B) powered from the ac line, this circuit will charge batteries up to 4 A-H and 12 vdc.

minal voltages up to 12 Vdc. Similar to the circuit shown in **fig. 2A**, it is based on 5-volt fixed regulators such as the LM-309, LM-340-05, or 7805 devices.

A constant-voltage charger is shown in **fig. 3**. The output voltage of the charger is set by the ratio of R1 and R2, and is determined by the equation:

$$V_o = 1.26\left(\frac{R2}{R1} + 1\right)$$

A series resistor, R3, is chosen to limit the short-circuit current to a maximum of A-H/10. The required charger output impedance is the resistance equivalent of V_o / I_{MAX}, where V_o is the open-terminal battery voltage and I_{MAX} is the maximum permissible charging current. For a 12-volt, 4 A-H battery, for example, the required impedance is 12/(4/10) = 12/0.4 = 30 ohms. We can solve the equation in the figure for R3 and place that resistance in series with the output of the regulator. The power rating of the resistor must be $V_o \times I_{MAX}$.

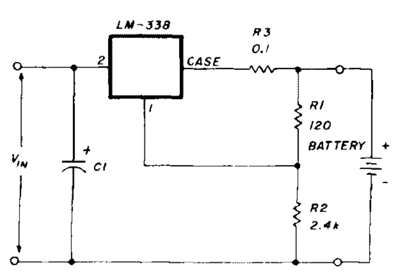


fig. 3. Constant-voltage charger uses ratio of resistor values to determine setting.

using bench power supplies

A bench power supply shouldn't be used to charge NiCd batteries unless it has both a variable output voltage control and a current-limiting control. Set the output voltage to exactly the full terminal voltage of the NiCd battery and adjust the current limiter for a short-circuit current equal to the A-H/10 value. Disconnect the output short from the power supply and connect the supply across the battery.

multiple-cell batteries

A large number of multiple-cell batteries are used in electronic equipment. Most are typically 6, 12, or 24-volt models. In most cases, these batteries are made up of individual AA, C, D, or F cells. I found it possible to take apart these battery packs and replace individual cells to restore the battery to normal operation. Some packs are put together with screws or snaps, while others are glued together.

My friend who uses a transcutaneous electronic nerve stimulator (TENS) unit for pain control (see last month's column) paid $90 each for the battery packs to power his device. One afternoon we took apart one of the packs he'd decided was bad, using a razor knife and lots of care. We found that the pack consisted of three AA cells connected in series. We went to a store that sold commercial solder-tab AA NiCd cells and returned with $18 worth of cells to make a "new" battery. I showed him how to solder them in, and then re-glued the plastic package; the pack lasted nearly 18 months.

If you don't know how to find a local source of commercial (as opposed to consumer) grade NiCd cells, then try calling the chief engineer at a local TV station. The portable video cameras used by TV news crews are powered by NiCd cells. It's a sure bet that the engineer will know a good source of fully rated cells.

When selecting cells for replacement, keep in mind several factors. First, of course, is the right size (AA, C, D, F) and the right A-H rating (as I said last month, not all C and D cells are created equal). Also keep in mind whether regular cells or solder-tab cells are needed. I've found that some consumer NiCd cells are in nonstandard packages. One brand of AA cells is a millimeter or so shorter than standard AA cells; as a result, intermittent operation is sometimes experienced. To avoid solder-shimming these cells or re-tensioning the contact spring, I simply avoid buying this brand and use standard-size batteries instead.

other batteries

Several other types of batteries are used in communications equipment. For mobile and some portable applications, for example, there's the lead acid automobile battery. These are the familiar batteries used to start automobile engines; though they're very heavy and quite dangerous because of their contents, they're popular because they're generally well behaved and easily available. In addition, many Amateur Radio sets are designed to operate from the nominal 13.6 Vdc produced by the typical automobile battery.

In addition to the 13.6-volt (nee "12 volt") battery, there are also 6, 24, 28, and 32-volt lead acid batteries on the market. Some of these are marine batteries, others are military batteries (28 Vdc), and still others are truck batteries. The terminal voltage can be increased by connecting batteries in series, while current availability is increased by connecting batteries in parallel.

Mobile operation is usually carried out with the regular vehicle battery. But in certain cases, it's wise to have a separate battery for the radio communications equipment in order to have battery power in the event of a main vehicle power supply failure. Boaters, four-wheel drive "boondockers," hunters, and others may want to consider the type of system shown in **fig. 4**. This system, common in recreational vehicles, powers the creature comforts separately from the vehicle battery. The point is to keep your communications capability, even if you accidentally discharge the vehicle battery by leaving the lights on or suffer some other problem. The backup battery could then be used to start the vehicle or summon help, depending upon the situation.

The charger will be a generator or alternator installed in the vehicle. Although the ideal system would be to have separate charging and regulating systems, that ideal isn't always achievable for certain practical reasons. Thus, we have a single charger and voltage regulator for two or more batteries. Isolation between the batteries is provided by a pair of large-current

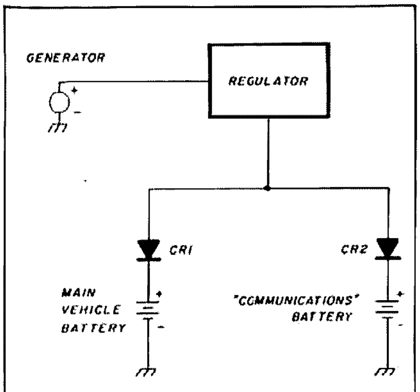


fig. 4. Simple method of charging main and auxiliary mobile batteries.

silicon diodes (CR1 and CR2). The rating of these diodes should be at least 1.5 times the maximum charge rate of the charger. In most cases, large stud-mounted diodes are used for CR1 and CR2, and they're mounted on a finned heat sink. In vehicular installations, keep in mind that ambient temperature is high in some locations, and will affect diode reliability.

For portable operations, some means must be provided to charge the lead acid battery. In most cases, a small gasoline or kerosene engine-powered generator is used to provide battery power. In some cases, an automotive type battery charger is needed to convert the ac output from the generator to dc for the battery. It's increasingly common, however, to find small 500- to 2000-watt gênerators that include a "12-volt" output that provides from 6 to 35 amperes for purposes of powering radio equipment or charging batteries.

Other forms of chargers are also used. Some people use wind power, while others use falling water (which is somewhat easier in isolated locations than you might think possible), and still others use sunlight. I once met a Swedish Pentecostal missionary who worked in the deserts of Sudan. In the area of Africa to which he was sent, the roads are littered with the corpses of dead animals — even camels — which should give you an idea of just how dreadful the place is. His organization doesn't allow him to set up camp without a 6-MHz Stoner Communications transceiver and an Amateur Radio transceiver (he uses a Kenwood TS-120). One thing that's plentiful in those latitudes is sunshine, so a set of solar panels (intended originally for boaters) was procured to charge the lead acid batteries. A 6-ampere charging system cost him about $2300 at the time it was purchased several years ago, but it's probably cheaper now.

Regular maintenance of lead acid batteries is relatively easy and absolutely essential. The water level in each cell must be checked periodically; those whose need for the battery is critical should check the level weekly. Although it's best to fill the cells with distilled water (because of the lack of additional chemicals), ordinary tap water will also work. The vents in the caps that cover the cells mustn't be blocked; if dirt obscures the opening, replace the cap or clean it.

Warning: lead acid batteries produce hydrogen as a normal by-product. If you fail to observe proper procedures, this hydrogen may cause the battery to explode, causing serious injury to people and damage to equipment.

Never* allow the battery to become overcharged.** ***Turn off all circuits connected to the battery — ***especially*** the charger — before disconnecting the wires to the battery. If current is flowing in those circuits, then a spark will occur . . . and that spark can create an explosion. This is not a hypothetical possibility, but a real danger. I've seen it happen twice in my career, and one time it darn near cost a fellow two-way radio technician his eyesight. He made the mistake of disconnecting the wires from a battery charger before turning off the charger and all peripheral circuits.

gel cell batteries

Another form of battery popular in portable radio equipment is the gel cell. I've seen these batteries in commercial, medical, and Amateur Radio equipment. Several years ago I worked with

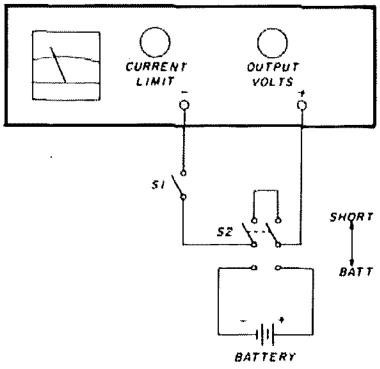


fig. 5. Method of adjusting current and voltage in charging system.

a piece of equipment that kept failing because of "premature" battery failure. The equipment manufacturer sent us a newly designed internal battery charger, but it too was deficient. All our battery chargers were high-tech models that depended upon sensing small variations in terminal voltage to determine a charge or discharge state. Unfortunately, the analog sensing circuitry had enough dc drift to produce bad results. In desperation, the engineer in our laboratory called the battery manufacturer — instead of the manufacturer of the device — and asked *him*. The manufacturer's applications engineer asked if we'd ever heard of Kirchoff's Voltage Law. Allowing that we'd heard that one before, we let the applications engineer guide us to a solution (see **fig. 5**).

The circuit shown in **fig. 5** shows a simple method of charging gel cells (and other forms of batteries). The charger power supply must have two features: a precisely controlled output voltage and a current-limit control. With switch S1 open, set the output voltage to exactly the value of the fully charged voltage of the battery, or perhaps a small amount higher (100 to 200 mV). Place S2 in the shorting position and then close S1. Adjust the current-limit control for a short-circuit current equal to the maximum permitted charge current of the battery (A-H/10 for many batteries). After the current and voltage are set, place switch S2 in the BATT position and charge the battery. When the battery voltage is less than the power supply output voltage, current flows into the battery. But when the battery voltage equals the power supply voltage, current flow ceases.

conclusion

Batteries can provide freedom of operation for electronic equipment. But they can also be a nuisance if not maintained correctly. Proper maintenance of the battery will provide long and reliable life.

ham radio

convert a $25 CB HT for 6 meters

New crystals, alignment put you on the air

Radio Shack's new TRC-501 is intended for unlicensed 49-MHz CB operation. While most units sold for this band commonly use a-m and super-regenerative receivers, this unit is a unique full-fledged fm transceiver aimed at the semi-professional user who needs inexpensive, very local communications. At its low price (about $25), this unit obviously can't be compared with commercial quality HTs — but it still represents a surprising value for Amateur experimenters. This article shows how to convert this transceiver for the 6-meter Amateur band.

The schematic supplied with the transceiver is unfortunately very tiny and impossible to read. (I did try enlarging the print to produce a more legible copy, but the optical limitations of my copying machine produced only larger, even more illegible prints.) Since very little other useful technical information accompanies the transceiver, I'll provide a quick description of the circuits used in this frugally engineered package.

receiver

The rf amplifier is a common-base stage. Most of the front-end selectivity is provided by L2, the interstage coupling transformer between the rf amplifier and mixer. Another bipolar transistor serves as the mixer stage. The first of two ceramic filters, an inexpensive wideband 10.7-MHz type commonly found in fm broadcast i-f stages, follows the mixer. A third-overtone crystal oscillator provides LO injection.

The heart of the receiver is a Motorola MC1355 integrated circuit. This chip provides all of the i-f functions, including the second LO oscillator and mixer, fm detection and audio squelch circuits. The second i-f is on 455 kHz. The ultimate receiver selectivity is determined by the 455-kHz ceramic filter. An LM386 audio amplifier delivers surprisingly good audio.

transmitter

The transmitter signal starts with a 16-MHz oscillator, triples, and finally ends up in a low-power amplifier stage. Direct fm — via a varicap modulator — is applied to the 16-MHz oscillator. A deviation control (RV1) is included in the audio chain. The internal electret mic element produces good quality audio.

order crystals

The first thing to do is order the crystals for the desired receiver and transmitter channels. The transmitter crystal operates at one-third the actual transmitting frequency. For example, for 52.525-MHz (the national simplex channel), order a crystal for 17.508333 MHz.

The receiver crystal operates 10.7 MHz below the desired receive frequency. Again, using 52.25 MHz as an example, the crystal would be on 41.825 MHz. Specify a third-overtone series-resonant cut when ordering.

Most crystal companies will gladly, and without cost, correlate new crystals against customer samples. For best results I suggest carefully removing the crys-

By Peter Bertini, K1ZJH, 20 Patsun Road, Somers, Connecticut 06071

tals from the TRC-501 and sending them along with your order. They'll be returned undamaged. Since I chose to order my crystals before the TRC-501 was available, I gambled and guessed that a 20-pF load capacitance was correct for the transmit crystals. I was wrong, and the transmitter was nearly 25 kHz low in frequency. By inserting a 22-pF capacitor in series with the crystal, I was able to persuade the crystal to oscillate on the proper frequency. This involved cutting a run on the bottom of the board. I strongly recommend sending the 49-MHz crystals to the crystal company for proper correlation on the new frequencies. Mention that these crystals are for 49.830-MHz operation. Otherwise, I'd suggest ordering crystals about 8.333 kHz higher in frequency than calculated to correct for my errors. (For 52.525 MHz, the crystal would be at 17.516666 MHz instead of 17.508333 MHz when specified for 20-pF load capacitance, fundamental cut.) Also be sure that the new wire lead crystals are physically no larger than the ones supplied with the TRC-501; if they're larger, you'll find (as I did) that you won't be able to fit the radio back into its case without expending considerable effort in repositioning the crystals. Most crystal manufacturers will have no problem in supplying a crystal package equal to or smaller than those supplied with the TRC-501.

disassembly

Opening the TRC-501 is somewhat of a challenge. Start by removing the belt clip from the rear of the radio and the battery compartment cover. This will expose a single phillips-head screw which must be removed. The front and rear covers are clamshelled together; looking into the battery compartment reveals two of the four plastic clips locking the pieces together. Try to pry the case open carefully while working on one of the small exposed hooks with a pick or small screwdriver. Once the case pops open, be careful not to misplace the call button or push-to-talk bar. The call button must be reinstalled exactly as removed upon reassembly — the button's switch shaft-hole is not symmetrically oriented.

Once the pc board is exposed, remove the phillips screw located at the top of the board. The board may be lifted and laid to one side of the front of the case, but be careful not to stress the speaker or mike leads unduly. Note that the component part numbers, referenced to the schematic, are silkscreened on the component side of the board. Remove the solder from the leads mounting crystals X2 and X3 carefully. Once the holes are completely clear of solder and the leads are free, remove the crystals.

transmitter alignment

When the new crystals arrive, install the transmit crystal at X3 and the receive crystal at X2. Receiver alignment requires an adjustable level signal source. Transmitter alignment requires a field-strength meter and some means of setting the frequency; either a counter or receiver equipped with a zero discriminator meter will be useful.

I found it easiest to tune the transmitter using a field-strength meter. Coils L6, L5, and L1 are peaked for maximum field strength with the antenna fully extended. These three coils are clustered together in the lower right-hand section of the pc board, below crystal X3. Repeak the coils several times until no further improvement is noted. Transmitter frequency is adjusted by coil L7, directly above X3. The coil wax should be removed before the coil is adjusted. Heat the wax with a small iron and use tissue paper to wick away the wax when it's molten. The coils might tend to peak with cores almost fully removed from the forms. By going further into the forms (i.e., clockwise, rather than upwards) there's more adjustment for raising frequency.

The transmitter deviation is controlled by RV1, located above X3. The audio sensitivity is very good, and the deviation limiting is excellent, as is the modulation symmetry and quality.

receiver alignment

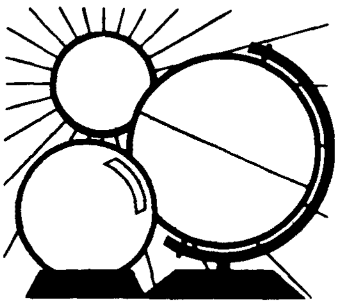
When crystal X2 is installed, a strong local signal should be audible. If not, the crystal may not be oscillating, and a slight readjustment of L4 may be needed. Remove the coil wax from L4 before adjusting. Coil L4 is below X2 in the bottom left-hand corner of the board. Receiver alignment is done by setting coils L4 and L2 for best quieting on a weak signal. Coil L2 is located near center at the board bottom. If the audio sounds slightly distorted, adjusting coil L4 will clear up the problem. (Although the factory setting is just fine, coil L3 may be adjusted for best recovered audio.)

performance

Because I had some difficulty finding a true 50-ohm termination point in this transceiver, the actual performance specs may be better than those I've measured, and certainly no worse. The manufacturer specifies 0.5-μV sensitivity for 20 dB-s/n; I measured about 2 μV. Transmitter power is rated at 10,000 μV/M at 3 meters, the maximum allowed by the FCC for unlicensed 49-MHz operation. Actual power, with a fresh alkaline battery, was measured at + 11 dBm (roughly 10 mW).

There's a dearth of 6-meter fm activity here in Connecticut, and I've converted only one of these units so far, so I can't boast about great DX contacts made with the TRC-501. For local line-of-sight communications, I suspect the TRC-501 will be hard to beat.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

summertime DX

You've probably noticed some changes in operating conditions between this spring and summer's DX season. One obvious difference is that the daytime bands are open for more hours, from early morning till late evening. This translates to more hours for DXing during your summer leisure time.

Even though the 15- and 20-meter bands are open for long skip, the 10- and 12-meter bands don't open often, and when they do, they're not open for very long. Signal levels also appear to be down. All these effects are attributable to the fact that the sun is in the northern hemisphere. During the daytime, the sun's ultraviolet light generates a thicker, more dense ionosphere over a larger area. Because this increase in ion production occurs in the D, E, and lower F regions of the ionosphere (i.e., 48 to 100 miles above the surface of the earth), it's more difficult for ions to diffuse and drift upward to the higher F2 layer, about 180 miles above the Earth. Consequently, the maximum usable frequencies (MUFs) don't build up as high in summer as they do during the other seasons of the year. The lower MUF signal loses more of its energy as it travels through the thicker, more dense D, E, and lower F regions. The loss can be up to 7 dB on 20 meters in the mid-latitudes. As a result, summertime long-skip conditions on 10 and 12 meters include shorter openings — if the bands are open at all — and weaker signal levels. Thunderstorm noise is also prevalent.

So what can we say that's positive about this season? Well, there are sporadic E short-skip openings. The *upper bands retain their MUFs longer,* and the MUFs are higher and nearly constant over the north polar regions because of the continuous daylight there. The sporadic E openings (up to 1200 miles and multiples) produce signal levels that are sometimes 25 dB greater than those received during long skip; they also account for 6-meter (and lower) band openings for a few hours nearly every day. You can also expect an improvement in 20 meters, with long-skip paths increasing in duration and available in more northern latitudes. This opportunity may provide contacts you haven't thought of working before. So the summer season is good for some decent DX after all!

last-minute forecast

The month opens with the lower bands favored in spite of the high probability of thunderstorm QRN in the late afternoon and evening. Solar flux levels are expected to be low during the first and second weeks; work DX from early morning till noon. A typical day might start with a mix of short-skip propagation from Sporadic E openings around sunrise and long-skip paths from the darkness periods traveling from the west but shifting to the east. As the sun rises — and with it, the ionospheric layer and consequent signal absorption — expect short-skip conditions to reoccur. If the signals weaken too much, move up to 15 or 20 for awhile. Look for E_S openings closer to noontime. Try the higher bands for E_S also. These higher frequencies are expected to be best around August 20. Don't expect many transequatorial one-long-hop openings this summer, but look for the E_S openings to the south. Geomagnetic disturbances may be experienced around August 4, 17, 22, and 28. These disturbances will affect the nighttime bands the most.

For the VHF/UHF enthusiast, the moon's perigee will occur on the 8th, with the full moon on the 9th. The Perseids meteor shower will occur from the 10th to the 14th, with a maximum rate of better than 50 meteors per hour expected on the 11th and 12th. This is an excellent shower to work with.

band-by-band summary

Six-meter sporadic E short-skip conditions will occur for 30 minutes to a couple of hours around local noon on some days, for this last good month of this summer's E_S season. Expect about 1000 miles per hop.

Ten, twelve, and fifteen meters will experience quite a few short-skip E_S openings and some long-skip openings during the 27-day solar flux peaks to southern areas of the world during daylight hours. Fifteen meters will be best for only an hour or two as the maximum usable frequency decreases during the late afternoon.

Twenty, thirty, and forty meters will be useful for DX communications to most eastern, western, and northern areas of the world during daylight hours and into the evening almost every day, via long skip to 2000 miles per hop or by means of short-skip E_S, with 1000-mile hops. The period of daylight is still relatively long, but will be noticeably shorter by the end of the month.

Thirty, forty, eighty, and one-sixty meters are all good for nighttime DX, even though the background noise is severe in the evenings. The direction of the openings will rotate around from the east to the south and then westward toward the morning. If you want to avoid thunderstorm QRN, Sporadic E propagation may be helpful in the early evening toward the east and south. Try the early morning hours for communication paths to the west and monitor WWV or WWVH on 2.5 and 5 MHz as beacons.

AUGUST

WESTERN USA

GMT	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	
PDT	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	
ASIA FAR EAST	30	30	30	40	30	30	30	30	20	20	20	30	40	30	30	30	30	20	20	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	20	20	30	30	30	30	NE
S. AFRICA	20	20	15	15	12	12	10	10	12	12	15	15	20	30*	20	20	20	20	20	30	20	20	20	20	E
S. AMERICA	10	10	10	12	12	12	12	12	15	15	20	20	20	30	20	20	20	20	20	20	15	15	12	12	SE
ANTARCTICA	15	15	15	15	20	20	20	30	40	40	40	40	40	30	30	30	30	30	30	20	20	20	15	15	S
NEW ZEALAND	12	12	12	15	15	20	20	30	20	20	20	20	20	20	20	15	15	12	12	12	10	10	10	12	SW
OCEANIA AUSTRALIA	12*	12	12	15	20	30	30	30	20	20	20	20	20	20	20	15	15	12	12	12	10	10	10	10	W
JAPAN	20	20	20	20	20	30	40	30	30	30	40	30	30	30	30	20	20	20	20	20	20	15	15	15	NW

MID USA

MDT	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	
ASIA FAR EAST	20	30	40	30	30	30	30	30	20	20	20	20	20	30	30	30	30	30	30	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	15	20	20	20	20	30	30	30	30	30	30	40	30	30	30	30	NE
S. AFRICA	20	20	15	15	12	12	10	12	12	15	15	15	20	20	30	20	20	20	20	30	20	20	20	20	E
S. AMERICA	12	10	10	12	12	12	12	12	15	15	15	20	20	30	30	20	20	20	20	20	20	10	15	12	SE
ANTARCTICA	15	15	15	20	20	20	20	20	30	40	40	40	40	40	40	30	30	30	30	20	20	20	20	15	S
NEW ZEALAND	12	12	12	15	15	20	30	20	20	20	20	20	20	20	20	20	15	15	12	12	12	12*	10	10	SW
OCEANIA AUSTRALIA	12*	12	15	15	20	30	30	30	20	20	20	20	20	20	20	15	15	15	12	12	12	10	10	10	W
JAPAN	20	20	20	20	20	30	30	30	30	30	20	20	30	30	30	30	30	30	20	20	20	20	20	20	NW
CDT	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	

EASTERN USA

EDT	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	
ASIA FAR EAST	20	30	40	30	30	30	30	20	20	20	20	20	20	20	20	20	30	30	30	30	30	20	20	20	N
EUROPE	30	20	20	20	20	20	20	15	15	20	20	20	20	20	20	30	40	30	30	40	30	30	30	30	NE
S. AFRICA	20	20	15	15	12	12	10	10	12*	12	12	15	15	20	20	30	20	20	20	30	20	20	20	20	E
CARIBBEAN S. AMERICA	12*	10	10	10	12	12	12	12	12	15	15	20	20	20	30	20	20	20	20	20	20	15	15	12	SE
ANTARCTICA	20	20	20	20	20	20	20	20	30	40	40	40	40	40	40	40	30	30	30	30	20	20	20	20	S
NEW ZEALAND	12	12	12	15	15	15	20	30	20	20	20	20	20	20	20	20	20	20	15	15	12	12	10	10	SW
OCEANIA AUSTRALIA	10	12	12	15	20	30	30	30	30	20	20	20	30	20	20	20	20	20	15	15	12	12	10	10	W
JAPAN	20	20	20	20	20	30	30	30	30	30	30	20	20	20	30	30	30	30	30	30	20	20	20	20	NW

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.
*Look at next **higher** band for possible openings.

ham radio

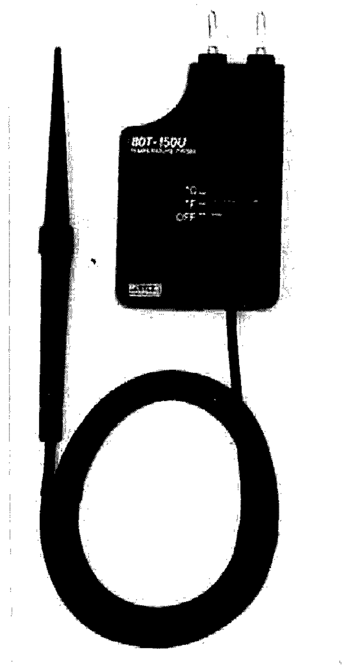
NEW products

universal temperature probe

The 80T-150U Universal Temperature Probe from the John Fluke Manufacturing Company, Inc., is a measurement accessory that converts any digital multimeter into a thermometer. The 80T-150U uses a P-N junction temperature sensor housed in a low thermal mass tip to provide fast, highly accurate readings.

Switch-selectable for readouts in F or C, the 80T-140U can make temperature measurements of live circuits, with 350-volt peak ac standoff capability. Small components can be accurately measured without cooling caused by the mass of the probe tip.

The 80T-150U has a range of − 58 to + 302 degrees F (− 50 C to + 150 C). Its basic accuracy is ± 1.8 degrees F (1 C) from 32 to 212 degrees F (0 to 100 C), thereby providing more accurate readings than most thermocouple devices. The unit uses a standard 9-volt battery, with a built-in battery check feature using the external DMM. Average battery life is 1600 hours.



The 80T-150U has a suggested U.S. list price of $129.

For more information, contact John Fluke Manufacturing Company, Inc., P.O. Box C9090, Everett, Washington 89206.

Circle #301 on Reader Service Card.

new tuning indicator

MFJ Enterprises, Inc. has released a new tuning indicator for users of TAPR TNC-1s, TNC-2s, and clones such as the MFJ-1270.

The MFJ-1273 ($49.95) lets you tune in hf, OSCAR and other non-fm packet stations fast because it shows you in which direction to tune your radio. Just center a single LED and you're precisely tuned in to within 10 Hz.

Twenty high-resolution LEDs and wide frequency coverage make tuning easy.

The MFJ-1273 tuning indicator plugs into the MFJ-1270 and all TNC-1s, TNC-2s, and clones that have the TAPR tuning indicator connection.

This MFJ product comes with a double guarantee. If ordered directly from MFJ, it may be returned within 30 days for a prompt refund (less shipping). It's also covered by MFJ's one-year unconditional guarantee.

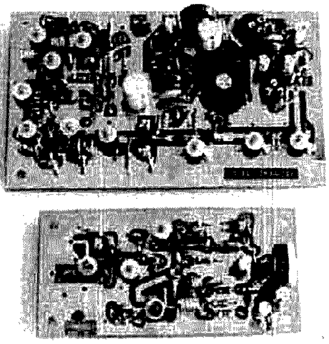
For more information, contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, Mississippi 39762.

Circle #302 on Reader Service Card.

ATV exciter/modulator for 33 cm

P. C. Electronics' Model TXA5-33 1-watt ATV exciter/modulator board for the 33-cm (902-928 MHz) band allows Amateurs of Technician class license or higher to transmit live-action color or black and white composite video from cameras, VCRs, or computers to other hams.

Most ATV activity has been on the 70-cm (420-450 MHz) band up until now. By also having a 33-cm ATV station, hams can now run full duplex video and audio crossband with another station on 70 cm. The TXA5-33 board should also make putting up a short-distance video link, crossband ATV repeater, bulletin board video repeater, and public service applications such as Space Shuttle video and weather radar video easy — without tying up one or both of the usual 70-cm ATV channels.



The 3 x 5-inch wired and tested TXA5-33 board accepts the standard 1-volt peak-to-peak composite video from any source. For sound, the P.C. Electronics FMA5 or XFMA5 Sound Subcarrier board is connected to the 4.5-MHz input pad of the TXA5-33 modulator circuit. The board takes 12 to 14 Vdc. At 13.8 Vdc, the board draws about 400 mA and puts out over 1 watt PEP into 50 ohms on the sync tip.

Using the 1-watt TXA5-33 and 23-element Tonna 20923 beams (16.2 dBd), the snow-free line-of-sight video range is 10 miles. This distance assumes a 4.2-dB loss in 100 feet of Columbia 1180C or Belden 9913 coax and the P.C. Electronics TVC-9G GaAsFET Downconverter ahead of any good TV set tuned to channel 3. Distance will be greater with shorter coax length or by mounting the antenna on the downconverter (every 6 dB doubles the distance).

Video quality is about as good as what you'd see fromyour own camera on your home VCR. The TV set's i-f bandwidth is the major limitation on resolution. Since ATV uses the same standards as broadcast TV, receiving is as easy as connecting a downconverter and antenna for Amateur frequencies to your TV set or VCR tuner set for channel 2, 3, or 4, depending on which one is unused in your area.

The TXA5-33 transmitter board is priced at $139; the TVC-9 GaAsFET downconverter board at $69; and the TVC-9G downconverter — ready to go in a cabinet with power supply — is $109. The Tonna 20923 23-element Yagi is $59. All prices include UPS surface shipping in the contiguous USA.

For a complete catalog of product information, contact P.C. Electronics, 2522 Paxson Lane, Arcadia, California 91006.

Circle #303 on Reader Service Card.

1.2-GHz transceiver

ICOM has announced the release of its compact new IC-1200, a 1.2-GHz transceiver for mobile or base operation that covers 1240-1300 MHz.

Featuring a simple-to-use front panel and a large LCD readout with an automatic dimmer circuit, the IC-1200 has 21 memory channels, 10

watts output power (including a low-power position for Novices), and memory scan. All subaudible tones are built-in.

The IC-1200 incorporates ICOM's AFC (Automatic Frequency Control) function, which automatically adjusts the receive frequency to the frequency of the transmitting station.

Two new options for the IC-1200 are the UT-28 digital code squelch unit, which incorporates a system of digital coding and decoding, and the UT-29 tone squelch unit, which encodes and decodes subaudible tones.

For further information, contact ICOM America Inc., 2380 116 Avenue N.E., P.O. Box C-90029, Bellevue, Washington 98009-9029.

Circle #304 on Reader Service Card.

packet radio handbook

In the new *Packet Radio Handbook* from TAB, Jonathan Mayo, KR3T, covers just about everything a beginner needs to know to put a packet radio station on the air. In addition, he discusses the history and development of packet radio; the people and organizations who introduced it to Amateurs; using packet with other modes for emergency communications and traffic handling, and more.

For newcomers, the book serves as a comprehensive introduction to packet radio theory and operation. Experienced operators will find a thorough review of basic techniques, along with more detailed technical information about modulation methods and networking principles, the use of protocols such as AX.25 and VADCG, an explanation of how TNCs work, and a discussion of bulletin board operation.

Also included are a complete glossary of common packet radio terms, listings of available equipment, and names and addresses of packet manufacturers, clubs, and newsletters.

The Packet Radio Handbook can be ordered from Ham Radio's Bookstore for $14.95, plus $3.50 shipping and handling.

software for Novices

Heathkit's updated computer-assisted instruction (CAI) software offers FCC-approved questions for all five Amateur Radio examination elements, including the latest Novice, Technician, and General class examinations. Menu-

NEW products

driven programs on disk feature all nine subelements plus the entire data base of FCC-approved questions. Users can create sample tests with multiple-choice questions and a CW practice program.

The software can be used with Heathkit, Zenith Data Systems, IBM, and other PC-compatible computers.

For information, contact Heath Company, Department 150-905, Benton Harbor, Michigan 40922. (In Canada, contact Heath Company, 1020 Islington Avenue, Department 3100, Toronto, Ontario M8Z 5Z3.)

Circle #305 on Reader Service Card.

new terminal program for C-64, 128

Kantronics has introduced a comprehensive terminal program written for use with the Commodore 64 and 128 computers. Offering split screen display, message buffers, disk storage, a type-ahead buffer, and other features, the C-128 program runs in 128 mode and provides for 80-character lines. It be used with almost all the Kantronics "smart" modems, including the KPC-1, KPC-2, KPC-4, KPC-2400, KAM, and UTU-XT/(P). Kanterm 64 and 128 are included on a single diskette. The suggested retail price is $29.95.

For details, contact Kantronics, 1202 E. 23rd Street, Lawrence, Kansas 66046.

Circle #306 on Reader Service Card.

compact VHF amplifier

The HL-160V25A is the compact version of the HL-160V25 VHF amplifier. The HL-160V25A has all the performance of the original, with a simplified control panel to reduce costs without sacrificing quality.

Multi-mode operation for FM, SSB, and CW plus a new GaAsFET type internal pre-amplifier make the HL-160V25A the best choice for high-power mobile or base operation with today's 25-watt output radios. The HL-160V25A produces 160 watts output from 25 watts drive across the entire 2-meter band. The amplifer can be keyed by a remote contact or by the rf signal from the transceiver or transmitter.

Currently in stock at local Encomm, Inc. dealers, its suggested retail price is $269.95. For details, contact Encomm, Inc., 1506 Capital, Plano, Texas 7507.

Circle #307 on Reader Service Card.

new dual-band antenna coupler

Larsen Electronics, Inc. has introduced its new AD-2/70 Dual-Band Antenna Coupler, which allows simultaneous operation in both VHF and UHF bands with a common dual-band antenna.

The AD-2/70 will connect separate VHF and UHF radios with a common dual-band antenna, such as one from the Larsen 2/70 series, or allow separate VHF and UHF antennas to be used with a single-port dual-band radio.

The Dual-Band Coupler, designed for operation in Amateur 2-meter and 70-centimeter bands, can be used for commercial VHF and UHF applications as well. Crossband isolation is suppressed to -50 dB or more, permitting interference-free simultaneous transmission or reception. Maximum power rating is 200 watts PEP composite VHF/UHF power.

For additional information, contact Larsen Electronics, Inc., P.O. Box 1799, Vancouver, Washington 98668.

Circle #312 on Reader Service Card.

weather satellite converter

Hamtronics, Inc. recently announced a new receiving converter for reception of weather fax pictures transmitted from satellites operating in the 137-MHz band. Basically a modified version of the CA144 2-meter Amateur converter, the CA137-28 Converter translates all signals received in the 136-138 MHz satellite band for reception on tunable 28-30 MHz wideband fm receivers. To make the conversion in dial frequency, simply subtract 108.000 from the frequency you want to receive. The receiver uses a low-noise front end to provide sensitivity of less than 0.2 μV. It operates on + 13.6 Vdc at 30 mA.

The CA137-28 Converter is available in three versions: wired and tested in the 4 x 4 x 2-inch cabinet shown at $69; in kit form at $49; and a kit for just the pc board module (less case) at $39. Shipping and handling is $3.

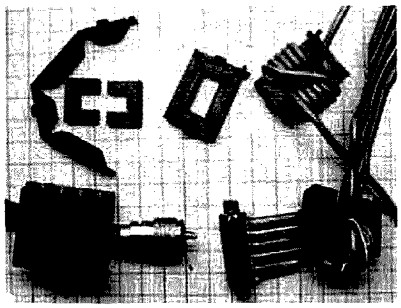
GaAsFET preamps of various types are also available for this band for those who'd like to take advantage of reduced cable loss by mounting a preamp at the antenna. An LNG-144 GaAsFET preamp enclosed in a 2 x 2-inch metal case is $49 wired and tested. An LNW-144 Preamp, which is the same basic circuit without a case, is available for $34 wired and tested or $19 in kit form. All three have a noise figure less than 1 dB. By using one of these preamps, the sensitivity of the converter can be made as low as 0.1 μV.

Other Hamtronics products include VHF and UHF transmitter and receiver modules and complete repeaters, "202"-type fsk modulators and demodulators for digital data interface, low-noise GaAsFET receiver preamps, 806-MHz scanner converters, transmitting and receiving converters for various amateur bands, VHF and UHF am receivers, repeater COR and CWID units, simplex and repeater autopatches and DTMF decoders, and many other products related to VHF and UHF fm systems.

For a complete 40-page catalog of Hamtronics™ products by return first-class mail, please send $1 ($2 for overseas mailing) to Hamtronics, Inc., 65-F Moul Road, Hilton, New York 14468-9535.

new interference suppression device

Computeradio has announced the availability of a new rfi suppression device, the TEXPRO Snap-On-Choke, which simplifies the application of an anti-interference technique that has long been appreciated by experts. Useful for minimizing interference to radios, TV sets, VCRs, TV converters, computers, digital data cables, telephones, process control and telecommunications systems, The TEXPRO Snap-On-Choke consists of a two-piece ferrite core and a plastic clamp. Its performance is similar to the toroidal ferrite cores, and is effective within a 0.5 to 200 MHz range. The choke can be clamped onto cables of a diameter up to 10 mm (0.4 inch) or can take



many turns of a thinner cable that will fit in the opening (9.9 x 21.6 mm). Installation does not require the removal of connectors or the unsoldering of connections — and doesn't void the warranty on equipment. A number of chokes can be snapped together if necessary.

The TEXPRO Snap-On-Choke is a "common-mode" choke that reduces radiation from the currents associated with cables — even shielded cables — acting as transmitting or receiving antennas. They can be used in place of a balun at the antenna feedpoint.

Single chokes are priced at $4.00 each. A package of four costs $15.00 plus $2.00 for shipping. Chokes come with a specification sheet and installation instructions. If you're not satisfied, you can return them within 30 days for a refund (less shipping).

For more information, contact COMPUTERADIO, Box 282, Pine Brook, New Jersey 07058.

Circle #308 on Reader Service Card.

computer-aided design

RF Notes No. 1, Version 3.0, aids in the design of resonant circuits, filters, basic stripline and microstrip projects, as well as cross-product and VSWR analysis. Version 3.0 incorporates improved schematic and graphics, in addition to allowing on-screen "what if" calculations. Priced at $85, the fully menu-driven program is easy to use and includes tutorial sections.

For details, contact Etron RF Enterprises, P.O. Box 4042, Diamond Bar, California 91765.

Circle #309 on Reader Service Card.

five new antennas

Mirage has announced the release of five new antennas, including three omnidirectional antennas of a "closed J" design and two upgraded designs for 440 MHz designed with through-the-boom elements rather than molded-on elements, for greater durability. ATV users will be especially interested in the 440-10X and 440-6X models, which were designed to replace the 440-6 and the 440-14.

Mirage will continue to replace parts and service older models. For details, contact Mirage/KLM Communications Equipment, Inc., P.O. Box 1000, Morgan Hill, California 95037.

Circle #310 on Reader Service Card.

novice "quick course"

In his new 21-day code and theory course, consisting of two long-play, stereo code cassettes and a fully illustrated Novice voice-class license preparation manual, Gordon West covers learning the code in a humorous and educational manner. The cassette code learning course is designed for students with absolutely no background in code copy.

Written by West and Fred Maia, W5YI, the accompanying manual includes every Novice class exam question, plus a thorough explanation of each as well as a discussion of each of the right and wrong answers. Several other chapters cover a detailed introduction to the Amateur Radio service.

Both the tapes and the book contain sections specifically for hams preparing administer the Novice test. An FCC Form 610 as well as a sample examination are included, as is a full-color ICOM frequency-band chart.

The course is available through local dealers or directly from Gordon West Radio School, 2414 College Drive, Costa Mesa, California 92626 for a total cost of $19.95 plus $2.00 for postage and handling.

Circle #311 on Reader Service Card.

✓ 116

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

THE ORIGINAL HAM SACK. Deluxe soft padded case for all popular handhelds with battery packs. Three zippered compartments for radio, antenna and accessories including spare battery pack. Belt loops and detachable shoulder strap. Tough Dupont Cordura™nylon. We are hams and we "know" you will like this case. Full refund guarantee. $12.50 includes shipping. Frank & Linda Reed, KC1DM & N1EUR, 15A Daniel Webster Drive, Hudson, NH 03051.

AMPLIFIER BREAKTHROUGH The current amplifier drives loads push-pull without internal voltage gain. Fastest, quietest circuit in transistor electronics. Plans for quieter audio amplifiers, ideal for home builders, all wattages, $15. Amplifiers Unlimited, Rt. 2, Box 139, Highmore, SD 57345.

HAM LICENSES SUPEREASY. Cut exam preps 50%. All classes. Free catalog. SASE. Bahr, 2549-H4 Temple, Palmbay, FL 32905.

SMART BATTERY CHARGER for gell-cells or lead acid batteries, by Warren Dion, W1BBH. See June '87 QST Magazine for circuit details. Complete kit, nothing else to buy, only $49.95 plus $3.50 s/h. Order #150-KIT. A & A ENGINEERING, 2521 W. LaPalma, Unit K, Anaheim, CA 92801. (714) 952-2114.

SELL: Amazing Mizuho SSB-CW Handheld. Mint $125. Argosy calibarator, crystal and audio filters, noise blanker. Mint $325. KLM Echo II, 432 MHz SSB/CW factory preamp very fine $185. MFJ Digi-Dial (counter becomes digital readout). New $20. Century 21 Calibrator and circuit breaker with meter $30. All guaranteed and UPS prepaid. WANT: Mocom-10, TIL 306, 308 readouts. Morsematic SSB squelch. WA6GER, 3241 Eastwood Road, Sacramento, CA 95821.

WANTED: WW2 Transceiver BC 654 (SCR 284) and PE 103 dynamotor. Also 1947/48 issues of Radio Craft and Radio & TV News magazines. E. Bircher, 108 Troy Drive, Slidell, LA 70461 (540) 649-7425.

COMPLETE STATION FOR SALE: Hammarlund HQ170A-VHF receiver, Hammarlund HX-50A transmitter, Mosley TA-33 Tri-Band antenna, Tri-Ex MW-35 crank-up tower (35' extended), Shure 444 station mike, Ham-M CDR rotor (needs minor repair) and Heathkit cantenna dummy RF load. Make offer for all or separate items; you ship. Call 301-948-0035 and leave name and number.

2M/1.25M/70CM MOBILE ANTENNA. The Austin Metro mobile provides tri-band operation with single 15" antenna atop car. $62.45. ($4.50 PH) including magnet mount. Ed Noll, W3GQJ, Sales Rep., PO Box 75, Chalfont, PA 18914.

FULL NTS TRAFFIC MESSAGE FORMS FOR PACKET OR RTTY on your IBM PC. MESSAGE-PAC works with any communications program to give you full Message Forms and formatted script/macro command files, ready to transmit. This is the one you've been waiting for. With user defined Pop-Up Help & Selection System that no one else offers. Can Pre-Load forms from disk. Only $29.95. DEMO DISK for $2.00. Write for information. Kalt and Associates, 2440 E. Tudor Rd, Suite 138, Anchorage, AK 99507. 907-248-0133. Charge Cards accepted.

WEST COAST SWAP SHEETS: Special introductory offer. SASE. WD6AFC, Bill, 4076 No. Hammel, Fresno, CA 93727.

ELITE + CODE PROGRAMS. Apple II + /c/e/GS. C-64/128. 37 modes. Graphics, wordprocessor, menus, lessons, speed techniques, drill, practice, print, teach, view modes; 1-100 WPM, variable sound, character, word spacing, and more. $49.95. Check/MO. COD's add $2. Other versions ($14.95–$44.95). $3.50 demo disk gives $2 off next purchase. Write: LARESCO, POB 2018, 1200 Ring Road, Calument City, IL 60409. 1-312-891-3279

ANALOG AND RF CONSULTING for the San Francisco Bay area. James Long, Ph.D N6YB (408) 733-8329.

APPLE COMPUTER p.d. Ham programs. Six disk sides: CW, OSCAR, logs, calcs, etc. $9.00 pp. Cashier's check/m.o. WA7ZYQ, 238 Tenth, St. Maries, ID 83861.

TEST EQUIPMENT WANTED. Don't wait -- we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at Skagitronics Co. (800) 356-TRON.

"HAMLOG" COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7-band WAS/DXCC. Full features. Apple $19.95, IBM or CP/M $24.95. KA1AWH, POB 2015, Peabody, MA 01960.

RV OPERATORS are invited to check in Sun 2 PMC, 14.240 ± 5. Tues, Thurs 8 PMC 3.880 ± 5. Good Sam RV Net. Info SASE KJ4RO.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521-5280.

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252.

NJ-NJ-NJ-NJ-NJ-NJ-NJ-NJ A Full-Service Ham-SWL-CB Scanner store in NJ. Discount Grand Opening Prices. Top performing radio systems for every budget. New 10 meter and VHF/UHF rigs. ARRL, Amphenol, Astatic, Astron, Azden, B&W, Bilal Belden 9913, Butternut, Clear Channel, KLM, Larsen, MFJ, Mirage, Mil Spec Cables, much more. Open M-F 10 AM-9PM. Sat 10 AM-7 PM. Buy and sell used gear and have qualified repair facility. ABARIS SYSTEMS, 276 Oriental Pl, Lyndhurst, NJ 07071 (201) 939-0015.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photodocumentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

NEED YAESU READOUTS: Texas Instruments TIL-306, TIL-308. R110 GRC Schematic. Want ICOM DV-21 VFO. Wagger, 3241 Eastwood Rd, Sacramento, CA 95821.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, New York 10538.

ANTENNAS G5RV Kit $29.95, KT5BA Multi-Band Ant. 160M-10M only $49.95. Antenna accessories, roller inductors, bal-Feed line, coaxial cable weather boot kit $9.50 and MUCH MORE! To order call (805) 646-9645. For catalog write Kilo-Tec, Box 1001, Oak View, CA 93022.

HOMEBREW PROJECTS LISTS. SASE, WB2EUF, Box 708, East Hampton, NY 11937.

FOR SALE: All new RCA 6816, RCA 8072, Eimac 8560A, Socket, Berylium oxide block, heat sink, 2- 4CX250B screen rings and ceramic chimneys. Richard Stevens, POB 118, Ashuelot, NH 03441. (603) 239-6079.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc, are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.

MAINE: September 12. Windsor Hamfest, sponsored by the Augusta Emergency Amateur Radio Unit. Southern Kennebec Agricultural Society Fairgrounds, Windsor. Flea Market, outdoor spaces free, indoor tables available. Forums, distributors, Saturday night homebaked beans and casseroles. Gate donation $2.00. Overnight camping $3/night or $5/two nights. Talk in on W1TLC 146.22/82 repeater. For information: Phil and Dot Young, W2JTH and W1TGY, 47 Longwood Avenue, Augusta, ME 04330. Telephone (207) 622-1385.

TENNESSEE: August 30. The Lebanon Hamfest sponsored by the Short Mountain Repeater Club. Cedars of Lebanon State Park, US 231, 7 miles south of Lebanon. All outdoors. Bring your own tables. Food and drinks available. For further information contact Mary Alice Fanning, KA4GSB, 4936 Danby Drive, Nashville, TN 37211.

INDIANA: August 16. The Lafayette Hamfest, Tippecanoe Co. Fairgrounds, on Indiana 25 in Lafayette. Indoor setup 5 PM to 8:30 PM EST Saturday night. No overnight camping on fairgrounds. Outdoor setup 5 AM.

OHIO: September 27. The Cleveland Hamfest Association's annual Hamfest and Computer Show, Cuyahoga County Fairgrounds, Berea. Doors open 8 AM to 4 PM. Early setup 6 AM. VE exams 9 AM. Tech forums and non-ham activities all day. Talk in on 146.52. Admission $3.50 advance; $4.00 at the gate. Inside tables $10. Outside flea market $4.00. Saturday night banquet. For more information write C.H.A., POB 81252, Cleveland, OH 44181-0252.

COLORADO: August 8. The Ski Country ARC will host its 6th annual Hamfest in conjunction with the Colorado Council of ARC summer meeting, CMC Building, 1402 Blake Avenue, Glenwood Springs. 9 AM to 3 PM. Admission free. Tables $5. Refreshments and lunch available. VE exams 9 AM. Videotapes, packet and AMSAT demos. For information contact Bob Ludtke, K9MWM, 406 Yale Circle, Glenwood Springs, CO 81601. (33) 945-8722.

ALABAMA: August 15 and 16. The Huntsville Hamfest and ARRL State Convention, Von Braun Civic Center, 700 Monroe Street, Huntsville. 9 AM to 5 PM Saturday. 9 AM to 3 PM Sunday. Amateur exams August 15 by CAVEC. Walk-ins welcome. Flea market, dealers/distributors and non-ham activities. All air-conditioned. No admission fee. Light refreshments available. Talk in on .34/.94. For further information contact Gwin Givens (205) 883-2760 or Don Tunstill (205) 536-3904.

OHIO: September 13. The Findlay Hamfest, Hancock County Fairgrounds, Findlay. Doors open 8 AM. Admission prior to 9/1 $3.00. After 9/1 $4.00. Flea market spaces $4.00 at door. Reserved indoor tables $6.00. For tickets and table reservations send check and SASE to FRC Hamfest, POB 587, Findlay, OH 45839.

WASHINGTON: August 22-23. The Radio Club of Tacoma presents Hamfair '87 and the ARRL Northwestern Division Convention, Pacific Lutheran University, Tacoma. Friday evening entertainment. Doors open 9 AM August 22. Registration $5.00 til August 12. $6.00 at the door. Banquet $10.00 by August 12. RV spaces $2.00. No hookups. Technical seminars, forums, flea market (tables $18/6') non-ham activities, VE exams all classes. For reservations and/or flea market tables write Al Wittich, KA7SBJ, 3832 Gay Rd E. Tacoma, WA 98443 or call Bill Morgan, W7GRP (206) 531-3821 or Marion O'Neal, WB7SQU (206) 838-3126.

MISSOURI: September 13. The Ozarks Amateur Radio Society will hold its 6th annual Ozarks Club Congress and Swapfest, City Park in Monett. Tailgating starts 9 AM. Potluck dinner

(continued on page 92)

ELMER'S NOTEBOOK

Tom McMullen, W1SL

oops!

Thanks to K4TG for pointing out an error. Please see the "short circuit" at the end of this month's column.

outguessing the ionosphere

From what I've been hearing on the bands and reading in newsletters and magazines, the 10-meter band ushered in the era of Novice Enhancement with an impressive demonstration of the fun it can provide. Reports abound of Novices working some terrific DX, and the enthusiasm shown by the lucky operators has been truly contagious. This is a perfect time for you Novices to get acquainted with Garth Stonehocker's "DX Forecaster" column in this magazine and make some notes about what you've heard or worked. You can then check against the column to build up a "prediction data base" for your location. Many an old hand at the Amateur game considers the thrill of outguessing the ionosphere to be as gratifying as collecting the QSL cards from the DX they've worked.

We'll continue last month's discussion of digital communications next month; in this column, we'll take a look at 220 MHz, a band that's sure to provide plenty of exciting local communications.

220 MHz: background

Years ago, Amateurs had a band known as 2-1/4 meters, or 112 MHz. A natural offshoot of this was another experimental band at 224 MHz — I say "natural" because the common practice was to use harmonics of lower frequencies to generate output on the VHF and UHF bands. Later, the 2-1/4 meter band was changed to 2 meters (144 MHz), but 224 remained unchanged, and the harmonic relationship obviously fell apart.

At the time, only true experimenters were willing to invest the time and money necessary to build separate stations for the 220-225 MHz "orphan." The appearance of surplus commercially made fm equipment on the 2-meter band encouraged manufacturers to produce equipment that would lead to our present crop of compact, solid-state, VHF-fm and all-mode rigs; the 220-MHz band, however, remained of little interest to most manufacturers — partly because of its very low occupancy, which was brought on by repeated attempts by government and commercial interests to grab all or part of the band for their use.

These attempts are still being made and fought off. There's an important difference, however, in that there's immensely greater occupancy now, and there will be more activity as Novices learn to use this part of the spectrum to its full potential. Consequently, finding equipment for 220 MHz won't be a problem.

equipment

A visit to any Amateur equipment dealer or a scan through Amateur publications will show that there are plenty of rigs to choose from. Among the most obvious are Kenwood's TM-3530A mobile and TH-31BT/31A hand-held; Icom's IC-375A base station, IC-37A and IC-38A mobile units, plus their IC-03AT and IC-3AT hand-helds; and Yaesu's FT-109RH hand-held. There will undoubtedly be more models available soon — perhaps even before you read this. Repeaters, too, are being manufactured for Amateur 220 MHz use.

While I'm talking about equipment, let me point out that a rig advertised as a mobile unit can be used as a base station too. A good (i.e., well filtered) power supply that provides the required 12 volts dc at sufficient current will afford many hours of home use. In fact, many operators get double duty out of their rigs by operating them both at home and in their cars. Some have done as I have — i.e., installed a newer mobile rig with more bells and whistles in the car, then put the older one to work at home.

antennas

Every major manufacturer of Amateur antennas offers models for the 220-MHz band. They're available in the form of beam (Yagi) antennas, groundplane antennas, magnet-mount and fixed-mount mobile whips of various sizes, and the ubiquitous "rubberduckie" that's so useful for portable and hand-held use.

Making your own antennas is always fun, however, and the size of the elements required for 220 MHz makes doing so much easier. Anything from new aluminum rod or tubing to salvaged TV antenna parts can be used to produce high-performance antennas that will let you extend your 220-MHz contacts to ever-expanding distances. You can find directions and

12 30. Special activities throughout the day. Free coffee and soft drinks provided by the Club. Talk in on 146.37/97. Free admission

INDIANA: August 2. The Porter County ARC presents the Northwest Indiana Hamfest and Computer Fair, 49'er Drive-in Theater, Rt. 49, north of Valparaiso. Gates open 7 AM, 6 AM for vendors. Admission $3.00. Children under 12 free. VE testing, food available. Free parking. Many beautiful area attractions. Talk in on 146.775/175 and 145.45/144 950. For further information: Rich Stahl, K9LBQ, POB 1782, Valparaiso, IN 46383.

WASHINGTON: August 22 and 23. The Radio Club of Tacoma presents Hamfair '87 and the ARRL N.W. Division Convention, Pacific Lutheran University, Tacoma. Friday evening entertainment for early arrivers. Doors open 9 AM on 8/22. Flea Market, commercial exhibits, VE testing, all classes. Registration $5.00 until August 12. $6.00/door. Banquet $10.00 by August 12. Flea market tables $18/6' includes one reservation. For reservations and/or flea market table write Al Wittich, KA7SBJ, 3837 Gay Road, E. Tacoma, WA 98443 or call Bill Morgan, W7GRP (206) 531-3821 or Marion O'Neal, WB7SOU (206) 838-03126.

IOWA: August 1 and 2. Summerfest '87 sponsored by the Cedar Valley ARC, Five Seasons Center, downtown Cedar Rapids, 8 AM to 5 PM Saturday and 8 AM to 3 PM Sunday. Admission $5 adult; $3 student advance. $6 adult, $4 student at the door. Seminars, FCC exams, vendors, flea market and non-ham activities. For information/reservations Duane Rinderknecht, 2825 - 23 Avenue, Marion, Iowa 52302. (319) 277-2761 days. (319) 377-2761 nights.

TEXAS: August 7-9. Austin SummerFest, sponsored by the Austin ARC and Austin Repeater Organization. Villa Capri Motor Hotel, 2400 North Interstate 35 near center of Austin. Indoor flea market. ARRL forum, tech program transmitter hunt and VE exams for all license classes. Saturday evening barbeque and Midnight Wouff Hong ceremony. Non ham arts and crafts and Austin Aqua Festival available during convention. General registration $5 advance; $7/door. Children 15 and under free. To register write Austin SummerFest, PO Box 13473, Austin, TX 78711.

MISSOURI: August 23. The St. Charles ARC will sponsor Hamfest 87 at Blanchette Park, St. Charles. 6:30 AM to 3.30 PM. Free admission and parking including handicapped spaces. $2. donation requested for tailgate flea market. Food available. Forums and FCC license exams at 10 AM. Talk in on 146.07/67 repeater and 146.52 simplex. Contact Eric Koch, NF0Q, 2805 Westminister, St. Charles, MO 63301 (314) 946-0948.

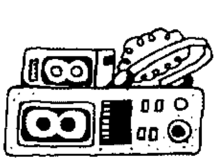
ONTARIO: September 19. The Hex-9 Group of the Barrie Amateur Radio Club is holding its third PACKET RADIO SYMPOSIUM co sponsored by and held at Georgian College, Barrie. Talks for beginners at 9:30 AM. Main discussions start 1 PM. Registration $5.00. Inquire Hex-9 Group, Box 254, Barrie, Ontario, L4M 4T2. Pre-register via packet VE3FJB-1

OHIO: August 23. The 11th annual Marysville Hamfest and Computer Show, Marysville Fairground. Admission $3.00 advance; $4.00 at the gate. Giant flea market. Free overnight camping available on grounds. Free entertainment Saturday night plus good food and lots of fun. For further information or tickets write Gene Kirby, W8BJN, 13613 US 36, Marysville, OH 43040 (513) 644-0468.

KENTUCKY: August 9. The Central Kentucky ARRL Hamfest sponsored by the Bluegrass Amateur Radio Society, Scott County High School, Longlick Road and US 25, Georgetown, 8 AM to 4 PM. Tech forums, license exams, awards and commercial exhibits in air conditioned facilities. Free outdoor flea market space with paid admission. Tickets $5/advance; $6/gate. Talk in on 146.16/76 repeater. For information or tickets SASE to Bill DeVore, N4DIT, 112 Brigadoon Parkway, Lexington, KY 40503.

TEXAS: August 8-9. The Panhandle Amateur Radio Club's 13th annual PARC-Golden Spread Hamfest, Inn of Amarillo, 601 Amarillo Blvd West, Amarillo. Starts 9 AM both days. Pre registration $5. Admission at door $6. Distributors, dealers, flea market tables $5. VE testing, walk ins only, both days. For more information write PARC Hamfest, Box 10221, Amarillo, TX 79116.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.



OPERATING EVENTS

"Things to do . . ."

August 2: The South Hills Brasspounders and Modulators will operate W3PIO to commemorate their 50th Hamfest and 200th anniversary of Allegheny County. 20, 15 and 10 meter General phone bands. For certificate QSL and SASE to Bill Gardiner, N3DXE, 4756 Child Drive, Pittsburgh, PA 15236.

August 16: The Arapahoe Radio Club will operate from several of Colorado's 14,000-ft mountain peaks. 1000-12000 MDT (1600-1800 UTC). SSB on 14.285 MHz. CW 14.060 MHz. A certificate will be available listing all Colorado Fourteeners Operations with checkoff of all stations worked. A special memento will be sent to any station working all Fourteener stations. Send QSL and legal SASE to K9AY, 7277 S. Clermont Drive, Littleton, CO 80122.

September 6: The Schaumburg Amateur Radio Club will operate WB9TXO from the Schaumburg Septemberfest site from 1500-2000Z. Suggested frequencies 7.250, 14.250 and 28.400 MHz. For a confirming certificate send QSL to SARC, POB 68251, Schaumburg, IL 60168-0251.

August 1-23. Special event station W9PAX (W9 Pan American Ten) will operate during the 10th Pan American Games being held in Indianapolis, August 7-23. For additional information contact Cornelius M. Head, WB9ZQE, 9046 Mercury Drive, Indianapolis, IN 46229. (317) 263-5281 (O) (317) 898-2792 (H).

September 5. The Old Pueblo Radio Club of Tucson will sponsor the 6th annual Labor Day Special Event Station W7GV from the OK Corral in Tombstone, Arizona, site of the famous shootout between the Earps and the Clantons in 1881. On new Novice/Tech 10 meter SSB frequencies. 0000Z September 5 to 2200Z September 7. For more information contact Bill Croghan, WB0KSW, 1854 W. Dominy Street, Tucson, AZ 85713. (602) 622-1535.

August 29: The Antietam Radio Association will operate special event station W3CWC to celebrate the 25th anniversary of the club. 80,40,20,15 and 10 meters phone, CW and RTTY. For a commemorative certificate send QSL and legal SASE to Special Events Station W3CWC, Antietam Radio Association, Inc., POB 52, Hagerstown, MD 21741.

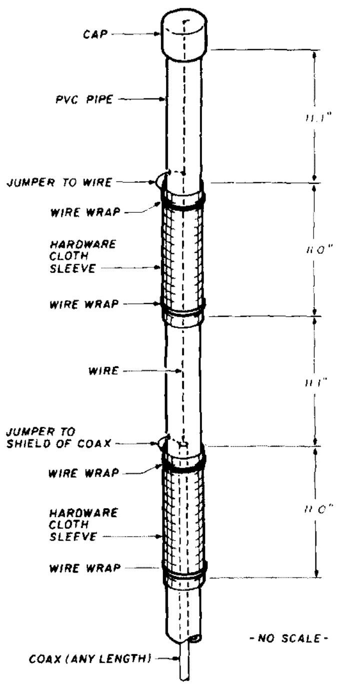


fig. 1. Two-meter antenna modified for 220 MHz.

formulas for building antennas in many handbooks; just drop a note or postcard to *ham radio's* Bookstore and ask for a catalog.

An increase in coverage that's especially useful for simplex operation can be obtained by using an antenna that's larger in terms of wavelength; a half-wave 220-MHz antenna is only seven inches longer than a quarter-wave whip for 144 MHz, and has more gain and a better angle of radiation from a car-top location. A 5/8-wave antenna element for 223 MHz is approximately 33 inches long, compared with 50 inches for 146 MHz. This difference in size isn't visible in most mobile antennas because a loading coil in the base of the antenna allows a shorter 2-meter radiator to perform as if it were 5/8-wavelength; it will be apparent, however, in home-station antennas such as multi-section verticals or ground-plane types with 5/8-wave vertical radiators.

A neat 2-meter antenna was described in Bill Orr's column in the May, 1987 issue of *ham radio* (see page 55). A few minutes with a calculator produced some dimensions that will let you adapt the 2-meter design for 220 MHz; see **fig. 1**. Note that neither version has elements that are exactly one-quarter or one-half of a free-space wavelength. A quarter-wave in space at 144 MHz is approximately 20 inches; at 223 MHz, it's approximately 13.2 inches. When you allow for the capacitive loading at the end of the elements, the coupling to the wire mesh "sleeves," and the dielectric effects of the PVC tubing, the element dimensions get shorter.

distances

The normal operating range of stations on the 220-MHz band is amazingly close to what can be expected on 2 meters. Well-located repeaters with good antennas can provide coverage that's virtually identical to 144 MHz. And because of the short space a wavelength occupies, peaks and nulls in signal strength experienced by stations in motion in urban or weak-signal areas aren't as bothersome at 220 as they might be at 144 MHz. There's also more "fill" of shadowed areas because of the slightly increased reflectivity of many materials at 220 MHz — but by the same token, many materials absorb 220 MHz more readily, thus causing some signal loss.

the ins and outs of repeaters

Band plans allow orderly occupancy of our sometimes crowded VHF spectrum and provide a basis for compatibility among various makes of fm transceivers and the repeaters through which they work. There's been a band plan for 220 ever since repeaters began appearing in VHF circles. Rather than use a lot of space to reproduce the entire 220-MHz band plan here, I'll just make a few comments about it.

The separation between a 220-MHz repeater's input and output frequencies is 1.6 MHz. When you transmit on 223.10 MHz from your mobile or handheld rig, the repeater retransmits your signal on 224.70 MHz; this higher frequency is where your receiver is listening. *Don't worry about 224.70 being out of the Novice "band"*; this type of operation is authorized by the FCC. At 223.10, your transmitter is operating within the limits of the Novice subband, which is what counts. (Novices beware: be sure that you never transmit "direct" on the repeater's output frequency. Never use the "reverse" or "inverted" mode of operation that's available on many current rigs.)

The band plan allows for 20 kHz between each repeater input; for example, 223.02, 223.04, 223.06, and so on. Each input has its corresponding output 1.6 MHz higher. There are a few "gotcha's," though. In some areas, 223.4 is designated as an input frequency. But if you add 1.6 to 223.4, you get 225.0. Obviously, you can't have a repeater output on the very edge of the band, so watch out for that one. In some areas, repeater input and output frequencies are reversed by local agreement; this usually means that the input is somewhere near the current input range, but the output of the repeater is 1.6 MHz *lower*.

Many simplex frequencies have been agreed upon, starting at 223.40 or 223.42 MHz and occurring every 20 kHz up to 223.88 or 223.90 MHz. Many stations use 223.50 MHz as a calling frequency to establish initial contact, then move to another simplex channel for a QSO.

This arrangement of repeater frequencies and simplex channels could change, however. Novices will no doubt want to use other modes such as CW, SSB, or packet in their segment of 220 MHz, and some changes will have to be worked out to accommodate them. I'll keep you abreast of changes in this column. For a listing of current repeaters and band plans on 220 MHz (and others), try *The ARRL Repeater Directory* — a neat, pocket-sized little guide that's been a best-seller everywhere. Again, *ham radio's* Bookstore has it.

For any of you who'd like to exercise your computer, **fig. 2** shows a short program that will generate a printout of common repeater and simplex

```
5 LPRINT "REPEATER AND SIMPLEX FREQUENCIES"
10 LPRINT "IN THE 220-MHz BAND"
15 LPRINT
20 A=222.28
30 B=224.98
40 I=0
50 FOR I=1 TO 150 STEP 1
60 A=A+.02
65 A=INT(A*100)/100
70 IF A<223.4 THEN PRINT A;"INPUT":LPRINT A;"INPUT"
75 IF A<223.9 AND A=>223.4 THEN PRINT A;"SIMPLEX":LPRINT A;"SIMPLEX"
80 IF A=<225 AND A=>223.9 THEN PRINT A;"OUTPUT":LPRINT A;"OUTPUT"
85 IF A=B THEN 100
90 NEXT
100 END
```

fig. 2. This short program generates a printout of common repeater and simplex frequencies on 220 MHz.

frequencies on 220 MHz. I've found that it works without **line 65** on the Radio Shack TRS-80® Model III and their PC-5 Pocket Scientific Computer. When used on an IBM PC® or compatible, however, the algorithm used in the computer causes it to "round up," which adds two extra decimal places! **Line 65** takes care of that glitch. I haven't tried it on other computers, but it's a simple BASIC program that should be easy to translate. The printout will be approximately 2-1/2 pages long.

ham radio

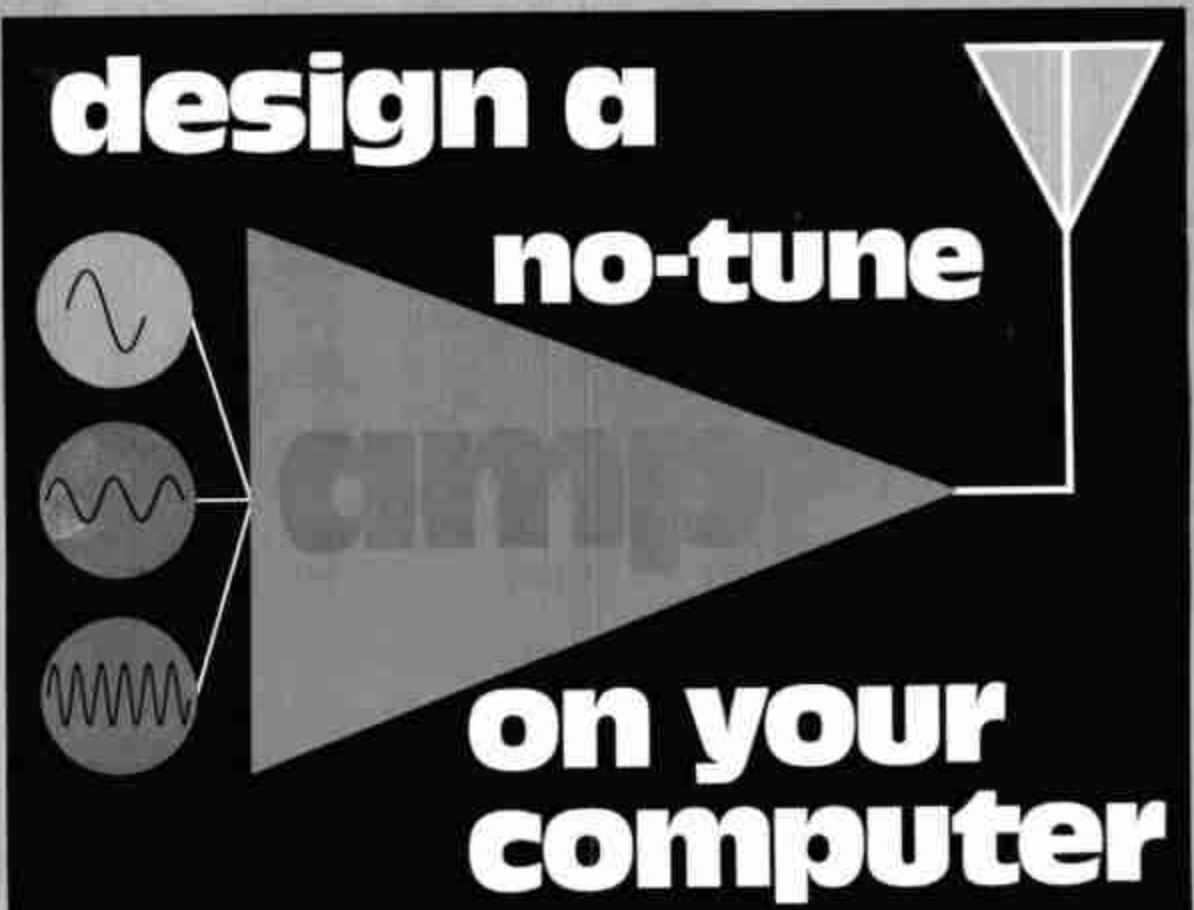
short circuit novice privileges

Because of a profusion of announcements early in the Novice Enhancement program, I used information *about Novice privileges on the 10-*meter band from a bulletin that was erroneous and missed a later correction. As a result, the information depicted in **fig. 1** of the June, 1987 column (page 95) is incorrect.

The correct Novice *10-meter modes* and segments are: CW and digital, 28.1 to 28.3 MHz; CW and voice, 28.3 to 28.5 MHz. — W1SL

SEPTEMBER 1987 / $2.50

ham radio magazine



hr

focus
on
communications
technology

ham radio magazine

SEPTEMBER 1987

volume 20, number 9

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Europe (via KLM air mail), $37.00
Canada, Japan, South Africa and other countries (via surface mail),
one year, $31.00, two years, $55.00, three years, $74.00

All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 99

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

**Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498**

contents

REFLECTIONS

a sentimental technocrat speaks

Thanks to the rapid evolution of electronic technology, Amateur Radio has seen significant changes during the past few years. While many of us fully endorse this advancement of the radio art, some of us are hopelessly sentimental technocrats who sense, over time, a qualitative change for the worse.

Therefore, I hereby submit my opinions on a wide range of issues confronting Amateur Radio. You won't find any engineering measurements, quantified results, or empirical thinking — just unabashed emotionalism. Some of it might be totally wrong. But that's OK — this is a guest editorial, not a technical article. Besides, there comes a time when a guy's got to say what he really thinks!

I've divided my list of issues into two parts: the stuff I don't like and the stuff I do like. "Stuff," by the way, can be anything. Nothing is too sacred for scrutiny.

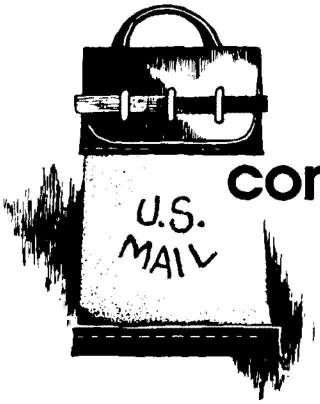
I really don't like:

PLL synthesizers, radios with memories, plastic cabinets, RCA jacks, circuit boards that disintegrate when they're touched, aluminum capacitors, fm, antenna traps, monolithic radios, on-board rf white noise generators (i.e., microprocessors), cable TV connectors, computer-generated QSL cards, articles that prove Yagis better than quads (even if they're right), FCC dockets (that's right — *all* of them), the Woodpecker, consumer electronics (Have you listened to your high-tech digital readout clock radio lately? I bought one because I like to wake up to music rather than a buzzer. But with my clock radio, I can't tell the difference!), multiple-choice code exams, profanity on the air, anti-antenna ordinances, cable TV "installation" charges, the technical quality of cable TV, fm stereo separation on cable systems, cable TV customer service, 2-meter video channels on cable systems, anything with 75-ohm impedance, disassociation of call districts, lamp dimmers, and the notion that the electromagnetic spectrum exists exclusively for commercial use.

On the other hand, I really do like:

Station logs, any radio component made from ceramic, glass, copper, or silver; oil-filled capacitors (toxic or not), vacuum variable capacitors, open-wire transmission lines, wire beam antennas (double extended zepps, stacked, phased, and fed with open-wire line), old QSL cards, old "How's DX?" columns (the kind with the grass-thatched shack, palm tree, and precarious dipole . . . where did the romance go?), Jeeves cartoons, the old smaller-sized *ham radio* and *QST* magazines (In high school I could hide them under my history book. How can kids hide them nowadays?); old E. F. Johnson, National, Collins, and Hammarlund radios; new radios built for radio performance, front panels that look like they belong on radios instead of computers, moonbounce, really big quads, astronomically large parabolas, computerized RTTY (Here's where a computer in the shack makes sense. Remember those noisy old electromechanical clunkers?), anything homebrew, GaAs LNAs, prop-pitch motors, PTO oscillators, houses built around the ham shack, XYLs who really do understand, kids who *don't* sneak ham magazines into history class, tubes, FETs (they're more like tubes than bipolars), volunteer examinations (taking the old exams was like visiting the Spanish Inquisition), mountain-top QTHs, analog clocks in the shack (especially the 24-hour brass ship's clocks with chimes), multicolored great circle maps *not* centered on Kansas (somebody in Kansas sure has a lot of clout), Silicon Valley and New York-area surplus dealers, *very* expensive linear amplifiers, high-dynamic range anything, low-noise anything, high-gain anything, anything simple yet adequate, anything slightly more complicated yet outstanding, two miles of buried No. 8 copper wire, full-size 160-meter antennas (they work on 80 as well), antennas too high for W2PV, receivers that confound W7ZOI (I'm still waiting for that day), my copy of Terman's *Radio Engineer's Handbook*, the W6GO QSL list, W6SAI's columns (he *really* likes tubes), ham dealers who sell used parts (good stuff, cheap), big heavy rigs with rf ammeters, Smith charts, swap meets (lots of good stuff, cheap), and finally, magazines crazy enough to publish this.

Robert J. Zavrel, Jr., W7SX
Tucson, Arizona



comments

code tests

The following is a copy of a letter addressed to the FCC by W. G. Welsh, who kindly shared it with us. — Ed.

I am pleased that you separated Technician and General written examination material. I had suggested this step in two previous letters I wrote to you about 30 years ago. I hope you will continue this trend and separate code tests. At present, Novice and Technician applicants must pass element 1-A, which is 5 WPM. At present, General and Advanced applicants must pass element 1-B, which is 13 WPM. The Extra Class requirement is element 1-C at 20 WPM.

I believe a separate code test requirement is appropriate for each class of license. I think the code test speeds would be appropriate at 4 (Novice), 8 (Technician), 12 (General), 16 (Advanced), and 20 (Extra Class).

Most beginning Novices send code about [at] 3 WPM. A code test at 4 WPM is more appropriate to their initial needs. The receiving test should be restored to forward-reading plain language text that just includes letters. Punctuation marks, numerals, and work signs were previously restricted to the sending test, which should still be suitable. The international requirement is that all applications for Amateur Radio operator licenses, that involve operating privileges below 30 MHz, must prove their ability to receive (by ear) and to send (by hand) the International Morse Code. I believe that this requirement can be met more easily at the Novice level than in the VEC (Technician through Extra Class) test program.

The jump from 5 to 13 WPM is drastic. Allowing candidates to move up in increments of 4 WPM should be beneficial. The proposed 8 and 12 WPM Technician and General code test requirements should help increase upgrades.

Similarly, the difference between 13 and 20 WPM is pronounced. The proposed 16 WPM Advanced code test requirement would be more conducive to upgrading to the 20-WPM Extra Class requirement.

Each step up in license grade entails increased operating spectrum wherein code may be used. It seems reasonable that the associated code test speed requirements should be separate and evenly stepped from the lowest to the highest license.

I have conducted Amateur Radio operator licensing courses every year since 1948. I am very active helping students. I know their problems and needs.

I hope you will give this matter prompt attention.

William G. Welsh, W6DDB, Burbank, California 91504-3297.

KLM balun

Dear HR:

Over the past year there it has been stated that some of our antennas (the 11X, 13LBA, and 16 LBX for 2 meters and the 14X and 22LBX for 220 MHz) had extremely high VSWR because the baluns were of the wrong length. These antennas are very sensitive; their leads must be as short as possible and balanced.

To remove any possibility of connecting the antennas improperly, we have developed a connector that is being supplied on all new antennas. In addition, anyone who has one of the antennas identified above may call us, toll-free, at 1-800-538-2140 (outside California) or 408-779-7363 (collect, from within California), and we'll be happy to send a connector free of charge.

W.M. Scott
Mirage/KLM Communications Equipment, Inc.
P.O. Box 1000
Morgan Hill, California 95037

novice calling frequency

Dear HR:

The 10-meter Novice band still needs an easy-to-remember calling frequency. I suggest making 28.1010 MHz the Novice 10-meter calling frequency. So, get in 28.1010 and give a call!

Henry Hampel, KA0TUP, St. Louis, Missouri 63116

elmers at work

Dear HR:

Received my *ham radio* today and as usual found some interesting reading. I think your new column, "Elmer's Notebook," by Tom McMullen, W1SL, can become a very useful part of the magazine, depending upon how it's handled.

We've established an Elmer committee in our club. Committee members are available to help out new Novices, and the committee has a supply of equipment to lend to the new hams until they can get some of their own.

In checking back on about 100 Novices licensed in the past several years, we found that may of them never became active. By actively working with new Novices as they become licensed, perhaps we'll be able to keep them interested.

George A. Diehl
Chatham, New Jersey 07928-1179

design a no-tune amplifier
with your personal computer

Try a broadband approach for instantaneous coverage

When a friend asked how a no-tune amplifier is designed, I had to say I really didn't know. It seemed, at the time, that if one were to use a low-*Q* circuit to convert the calculated plate load impedance to some other value — say 50 ohms — and then follow it with a symmetrical multi-section low-pass filter for that impedance, a semblance of a "no-tune" amplifier could be designed. Because some circuit analysis would appear to be necessary, it occurred to me that a personal computer could be an important tool in such a project.

To be truly "no-tune," an amplifier should be capable of operating over its intended range without being retuned; that is, its efficiency and power output should not be degraded. An rf power amplifier must have a tank circuit of sufficient *Q* to maintain a sinusoidal voltage on the plate, but the broadband requirement would seem to be a tank of low *Q*. There are economic factors to consider (how many components? what quality?) and, as it developed, questions about how many unknown currents would have to be calculated; this has a direct bearing on the complexity of the calculations.

The design described here developed from the original assumptions of a low-*Q* tank followed by a Chebyshev five-element low-pass filter. Partial circuits are shown in **figs. 1A** and **1B**.

tank design

Two obvious possibilities for the tank design are Pi-section and L-section tank circuits. In the former, *Q* is selectable (down to some minimum value), and in the latter, it usually isn't. Because the no-tune concept requires a lower *Q*, and because there's one less component, the L-section was chosen. This particular design is based on an amplifier with two 3-500Zs whose plate load resistance has been calculated as 2080 ohms. The design center frequency is 14.2 MHz. The amplifier also has plug-in tank and filter circuits (shades of World War II!), but that bears little on the design calculations.

L-section calculations

The algebraic equations for the tank circuit design, available from several sources,[1] are:

$$X_L = \sqrt{R1 \cdot R2 - R2^2}, \text{ and}$$
$$X_C = (-R1 \cdot R2) \,/\, X_L) \text{ for } R1 > R2$$

A small BASIC program for computing the values is provided in **fig. 2**. Although *Q* isn't mentioned in the program, it can be calculated easily in this case by:

$$Q = X_L \,/\, R2 = 318.6/50 = 6.372$$

The value calculated is adequately low for our purposes, but too low to be used without some kind of a follow-up filter; one wouldn't build an amplifier with only these characteristics, however. **Figure 3** shows the values of *Q* for L-sections that convert to 50 ohms. Coincidentally, they're the minimum values obtainable with the Pi-section.

By W. J. Byron, W7DHD, P.O. Box 2789, Sedona, Arizona 86336

the low-pass filter

Low-pass filters can be designed either from scratch or from tables produced by others.[2] The first filter selected has the following characteristics:

f (-3 dB): 1.638 MHz
f(-20 dB): 2.349 MHz
f(-50 dB): 4.48 MHz
L1, L5 (μH): 4.377
C2,C4 (pF): 3300
L3 (μH): 9.747

These numbers represent the values necessary for the listed frequencies. The table from which this filter came lists filters designed around "standard-value" components — in this case, the 3300-pF capacitors. As a result of this compromise, the VSWR of the network terminated by 50 ohms will be 1.06. The component values for a 10X increase in frequency will be one tenth of the values shown for the capacitors and inductances. The latter values were used for the first investigation. Another filter was designed from scratch (with the aid of the W1JR/WA1GRC CAD program[3]); the results are also presented here. It was selected to have the same 16.38-MHz cutoff as the filter above. Both have the Chebyshev response.

The amplifier's performance can be simulated by actually calculating all the voltages and currents around the circuit. The combination of the L-section and five-element filter plus the 50-ohm terminating resistor makes a four-unknown set of equations. Power output is $R2 \cdot I_4^2$. The plate voltage is indicat-

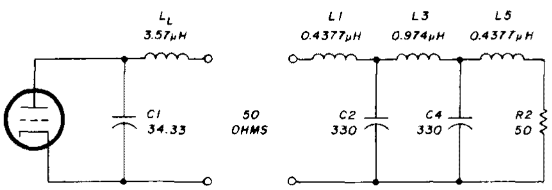


fig. 1A. Basic matching circuit: the L-section on the left transforms 2080 to 50 ohms; the symmetrical low-pass filter on the right operates at 50 ohms input and output, and has a cut-off frequency of 16.38 MHz.

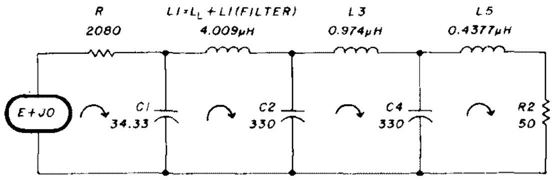


fig. 1B. Basic matching circuit: inductances L_L and L1 are combined into a new inductance, L1. The four loop currents used in deriving the equations in the text are shown with their orientation.

```
10 REM  R1 MUST BE LARGER THAN R2
20 INPUT "ENTER THE LARGER RESISTANCE";R1
30 INPUT "ENTER THE SMALLER RESISTANCE";R2:PRINT
40 XL = SQR(R1*R2-R2^2)
50 XC = -(R1*R2)/XL
60 PRINT "XL = ";XL;" Ohms, and""   XC = ";XC; " Ohms":PRINT
70 INPUT "ENTER THE FREQUENCY IN MHZ";F:PRINT
80 F = F*1000000!
90 W = 2*3.14159*F
100 PRINT "L = ";(XL/W)*1000000!;"  Microhenrys"
110 PRINT "C = ";-(1/(W*XC))*1E+12;" Picofarads"
120 END
RUN
ENTER THE LARGER RESISTANCE? 2080
ENTER THE SMALLER RESISTANCE? 50

XL =  318.5906  Ohms, and   XC = -326.4377  Ohms

ENTER THE FREQUENCY IN MHZ? 14.2

L =  3.570797   Microhenrys
C =  34.33459  Picofarads
Ok
```

fig. 2. BASIC program for computing L-section elements. The values shown for L and C are for the example described in the text.

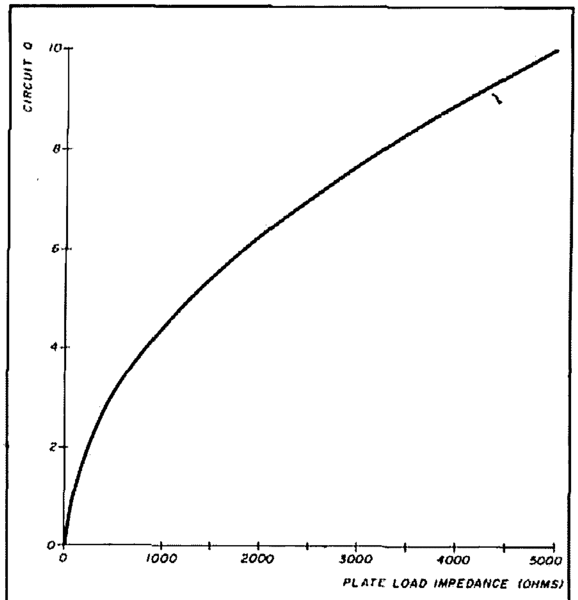


fig. 3. The values of Q available for L-sections and the minimum values available for Pi-sections. The curve applies only to sections that transform impedances to 50 ohms.

ed as "E" in **fig. 1B**. Four equations are needed to solve for the four currents (Kirchoff's loops require this). All have complex coefficients. The equations below are in simplified form, but they're the ones that must be solved:

$$I_1(R_p + X_{C1}) - I_2(0 + X_{C1}) + I_3(0 + 0) + I_4(0 + 0) = (E + j0) \quad \text{(1A)}$$

$$-I_1(0 + X_{C1}) + I_2(0 + X_{C1} + X_{L1} + X_{C2}) - I_3(0 + X_{C2}) + I_4(0 + 0) = (0 + j0) \quad \text{(1B)}$$

$$I_1(0 + 0) - I_2(0 + X_{C2}) + I_3(0 + X_{C2} + X_{L3} + X_{C4}) - I_4(0 + X_{C4}) = (0 + j0) \quad \text{(1C)}$$

$$I_1(0 + 0) + I_2(0 + 0) - I_3(0 + X_{C4}) + I_4(R_2 + X_{L5} + X_{C4}) = (0 + j0) \quad \text{(1D)}$$

A short program following the simplified form above is used to evaluate the currents. The only real numbers in the equations are R_p, R_2, and E, plus the leading zeros inside the parentheses. All other numbers are imaginary. The X_L's are intrinsically positive, and the X_C's are negative ($X_C - j/(2\pi fC)$). The "coefficients" program is listed in **fig. 4. Lines 100** through **240** provide a listing of the reactances, which were useful during the design. They can be eliminated if desired, because the coefficients themselves are produced in **lines 250** through **510** (including, of course, **lines 10** through **90**). An example of the output of the coefficients program is shown in **fig. 5**.

Now the equations must be solved. One of the best

```
10 REM: SAVED AS "CHEBS"
20 C1 = 37'*1E-12
30 L1 = 4.009*.000001
40 C2 = 330*1E-12
50 L3\= .9747*.000001
60 C4 = 330*1E-12
70 L5 = .438*.000001
80 R1 = 2080
90 R2 = 50
100 LPRINT"FREQ    XC1-OHMS   XL1-OHMS   XC2-OHMS   XL3-OHMS   XC4-OHMS    XL5-OH
MS"
110 LPRINT"____   ________   ________   ________   ________   ________   _______
_"
120 LPRINT
130 A$ = "##.##  ####.##    ####.##    ####.##    ####.##    ####.##    ####.##"
140 FOR F =14.2 TO 14.22 STEP .02
150 W = 2*3.14159*F*1000000!
160 XC1 =-1/(W*C1)
170 XL1 = W*L1
180 XC2 =-1/(W*C2)
190 XL3 = W*L3
200 XC4 =-1/(W*C4)
210 XL5 = W*L5
220 LPRINT USING A$;F,XC1,XL1,XC2,XL3,XC4,XL5
230 NEXT F
240 LPRINT:LPRINT
250 LPRINT"        COEFFICIENTS FOR GAUSS-JORDAN ELIMINATION"
260 LPRINT
270 LPRINT"  REAL    ,   IMAG    REAL , IMAG    REAL , IMAG    REAL , IMAG    REAL
 , IMAG"
280 LPRINT"_______________  _____________  _____________  _____________  _____
_________"
290  B$=  " #####.##,####.##  ###.##,###.##  ###.##,###.##  ###.##.###.##  ####.
##,###.##"
300 FOR F =14.2 TO 14.22 STEP .02
310 W = 2*3.14159*F*1000000!
320 XC1 =-1/(W*C1)
330 XL1 = W*L1
340 XC2 =-1/(W*C2)
350 XL3 = W*L3
360 XC4 =-1/(W*C4)
370 XL5 = W*L5
380 R1 = 2080!
390 R2 = 50!
400  A1 = R1:B1=XC1:A2=0:B2=-XC1:A3=0:B3=0:A4=0:B4=0:A5=3000:B5=0
410  S1=0:T1=-XC1:S2=0:T2=XC1+XL1+XC2:S3=0:T3=-XC2:S4=0:T4=0:S5=0:T5=0
420  U1=0:V1=0:U2=0:V2=-XC2:U3=0:V3=XC2+XL3+XC4:U4=0:V4=-XC4:U5=0:V5=0
430  Y1=0:Z1=0:Y2=0:Z2=0:Y3=0:Z3=-XC4:Y4=R2:Z4=XC4+XL5:Y5=0:Z5=0
440 LPRINT"FREQUENCY =";F;"MHz"
450 LPRINT USING B$; A1,B1,A2,B2,A3,B3,A4,B4,A5,B5
460 LPRINT USING B$; S1,T1,S2,T2,S3,T3,S4,T4,S5,T5
470 LPRINT USING B$; U1,V1,U2,V2,U3,V3,U4,V4,U5,V5
480 LPRINT USING B$; Y1,Z1,Y2,Z2,Y3,Z3,Y4,Z4,Y5,Z5
490 LPRINT"------------------------------------------------------------"
500 NEXT F
510 END
```

fig. 4. BASIC program for calculating the coefficients for the Gauss-Jordan elimination solutions.

FREQ	XC1-OHMS	XL1-OHMS	XC2-OHMS	XL3-OHMS	XC4-OHMS	XL5-OHMS
14.20	-302.92	357.69	-33.96	86.96	-33.96	39.08
14.22	-302.50	358.19	-33.92	87.09	-33.92	39.13

COEFFICIENTS FOR GAUSS-JORDAN ELIMINATION

REAL , IMAG	REAL , IMAG	REAL , IMAG	REAL , IMAG	REAL , IMAG
FREQUENCY = 14.2 MHz				
2080.00,-302.92	0.00,302.92	0.00, 0.00	0.00, 0.00	3000.00, 0.00
0.00, 302.92	0.00, 20.80	0.00, 33.96	0.00, 0.00	0.00, 0.00
0.00, 0.00	0.00, 33.96	0.00, 19.04	0.00, 33.96	0.00, 0.00
0.00, 0.00	0.00, 0.00	0.00, 33.96	50.00, 5.11	0.00, 0.00
FREQUENCY = 14.22 MHz				
2080.00,-302.50	0.00,302.50	0.00, 0.00	0.00, 0.00	3000.00, 0.00
0.00, 302.50	0.00, 21.78	0.00, 33.92	0.00, 0.00	0.00, 0.00
0.00, 0.00	0.00, 33.92	0.00, 19.25	0.00, 33.92	0.00, 0.00
0.00, 0.00	0.00, 0.00	0.00, 33.92	50.00, 5.22	0.00, 0.00

fig. 5. Sample of the output of the "Coefficients" program. The solution is for two frequencies, 14.2 and 14.22 MHz. The reactances are above, and the coefficients are below.

techniques available is known as the Gauss-Jordan elimination. The main program, listed in **fig. 6**, is taken from what is probably the best source of scientific and engineering programs currently available.[4] Its input requires that the coefficients be entered in order; the first real number of the first equation (R_p in this case) through the imaginary component of the last constant (j0 of the right-hand side of the equation for I_4.

solving the problem

The first attempt was to use the values for the calculated L-section above, followed by the filter from reference 2. Because the L-section has an inductor as the output and the filter was selected to have an inductor as an input element (one can also choose a filter with a capacitive input), these were combined into one inductor (see **fig. 1B**). With the values so determined, they were typed into the coefficients program. It will yield pages of coefficients, depending on the range and increments (steps) one chooses in the FOR-NEXT loops.

As it turned out, although an amplifier constructed around these components would have worked moderately well, it would show the effects of the compromises in the filter designed around standard values. By sweeping the frequency, it was easy to see that the L-section capacitor was too small. Nevertheless, the capacitor would have delivered 90 percent of the power delivered by the matched L-section alone. The next step was to "tune" C1 by modifying the coefficients program to fix the frequency at 14.2 MHz, and then vary the value of C1. The results of this are shown in **fig. 7**. The output follows the typical resonance response, just as if the capacitor were tuned by hand in a real amplifier. From this plot, it's evident that the value for C1 should be changed from 34 to 37 pF. The results are shown in **fig. 8**; also shown is the response of an L-section and filter designed for that use, with exact-size components employed.

The output of the Gauss-Jordan routine, an example of which is shown in **fig. 9**, gives currents in both polar and Cartesian coordinates. The "magnitude" is the same as a scalar value. If it appears as, say, the current in R2, there's no complication; use it as it stands. If it's necessary to know what current is flowing in C2, however, one must take the vector difference between the two currents flowing in "opposite" directions through C2. The source voltage for these problems is arbitrary; I've specified it as E + j0. All other listed phase angles are referenced to that voltage. They're important only when the design requirement might be a specific phase angle. Here it's not a design criterion — but as described above, the phase angles must be considered when determining the ratings of components used in the amplifier.

sizing components

The curves of **fig. 7** were calculated by assuming an ac plate voltage of 3000. The power outputs were between 900 and 1100 watts. It requires just over 3500 volts to achieve 1500 watts output. When 3500 + j0 is used for the input to the program, I_4 reaches 5.39

fig. 6. The Gauss-Jordan elimination routine in BASIC. (Reproduced from *BASIC Programs for Scientists and Engineers*, by Alan R. Miller, copyright 1982, SYBEX, Inc., Alameda, California 94501. All rights reserved.)

```
10 REM SIMULTANEOUS SOLUTION OF COMPLEX EQUATIONS
20 REM BY THE GAUSS-JORDAN ELIMINATION TECNIQUE
30 REM
40 A$ = "##.###^^^^ "
50 B$ = " = ##.###^^^^"
60 C$ ="  ##.#####   ##.#####    ##.#####    ###.#####"
70 M1% = 8
80 DIM Z(8),A(8,8),C1(8),W(8,1),B(8,8),I2%(8,3)
90 DIM D4(4,4),D5(4,4),V(4,2)
100 P8 = 180!/3.14159
110 REM
120 REM
130 REM
140 GOSUB 410:REM INPUT ROUTINE
150 GOSUB 790: REM GAUSS-JORDAN ROUTINE
160 REM
170 IF (N1%>5) THEN 250
180   PRINT "        MATRIX CONSTANTS"
190 FOR I% = 1 TO N1%
200   FOR J% = 1 TO N2%
210     PRINT USING A$;A(I%,J%);
220   NEXT J%
230   PRINT USING B$; Z(I%)
240 NEXT I%
250 PRINT
260 IF (E1% = 1) THEN 400
270 PRINT"   REAL      IMAGINARY     MAGNITUDE      ANGLE"
280 PRINT
290 FOR I% = 1 TO N2%/2
300   J% = 2*I% - 1
310   R2 = C1(J%)
320   I6 = C1(J% + 1)
330   M3 = SQR(R2*R2+I6*I6)
340   IF (R2>0) THEN A1 = ATN(I6/R2)*P8
350   IF (R2 = 0) THEN A1 = SGN(I6)*90
360   IF (R2<0) THEN A1 = ATN(I6/R2)*P8+180
370 PRINT USING C$;R2,I6,M3,A1
380 NEXT I%
390 PRINT
400 GOTO 140: REM NEXT SET OF EQUATIONS
410 REM
420 REM INPUT DATA
430 REM
440 INPUT"  HOW MANY EQUATIONS";N1%
450 IF(N1%>(M1%/2)) THEN 440
460 IF(N1%<2) THEN 1880
470 N2% = N1%
480 FOR I% = 1 TO N1%
490   PRINT "EQUATION";I%
500   K% = 0
510   L% = 2*I% - 1
520   FOR J% = 1 TO N1%
530     K% = K% + 1
540     PRINT"REAL ";J%;"  ";
550     INPUT D4(I%,J%)
560     A(L%,K%) = D4(I%,J%)
570     A(L%+1,K%+1) = D4(I%,J%)
580     K% = K% + 1
590     PRINT"IMAG ";J%;"  ";
600     INPUT D5(I%,J%)
610     A(L%,K%) = -D5(I%,J%)
```

```
620      A(L%+1,K%-1) = D5(I%,J%)
630    NEXT J%
640    INPUT"REAL CONST "; V(I%,1)
650    Z(L%) = V(I%,1)
660    INPUT"IMAG CONST ";V(I%,2)
670    Z(L%+1) = V(I%,2)
680 NEXT I%
690 PRINT: REM PRINT ORIGINAL MATRIX
700 FOR I% = 1 TO N1%
710    FOR J% = 1 TO N2%
720      PRINT D4(I%,J%);D5(I%,J%);
730    NEXT J%
740    PRINT V(I%,1);V(I%,2)
750 NEXT I%
760 N1% = 2*N1%
770 N2% = N1%
780 RETURN: REM FROM INPUT ROUTINE
790 REM GAUSS-JORDAN ROUTINE
800 REM
810 REM
820 E1% = 0
830 I5% = 1
840 N3% = 1
850 FOR I% = 1 TO N2%
860    FOR J% = 1 TO N2%
870      B(I%,J%) = A(I%,J%)
880    NEXT J%
890    W(I%,1) = Z(I%)
900    I2%(I%,3) = 0
910 NEXT I%
920 D3 = 1
930 FOR I% = 1 TO N2%
940 REM
950 REM
960 REM
970 B1 = 0
980 FOR J% = 1 TO N2%
990    IF (I2%(J%,3)=1) THEN 1080
1000    FOR K% = 1 TO N2%
1010      IF (I2%(K%,3)>1) THEN 1850
1020      IF (I2%(K%,3)=1) THEN 1070
1030      IF (B1>=ABS(B(J%,K%))) THEN 1070
1040      I3% = J%
1050      I4% = K%
1060      B1 = ABS(B(J%,K%))
1070 NEXT K%
1080 NEXT J%
1090 I2%(I4%,3) = I2%(I4%,3)+1
1100 I2%(I%,1) = I3%
1110 I2%(I%,2) = I4%
1120 REM
1130 IF (I3% = I4%) THEN 1270
1140 D3 = -D3
1150 FOR L% = 1 TO N2%
1160    H1 = B(I3%,L%)
1170 B(I3%,L%) = B(I4%,L%)
1180 B(I4%,L%) = H1
1190 NEXT L%
1200     IF (N3%<1) THEN 1270
1210     FOR L% = 1 TO N3%
1220       H1 = W(I3%,L%)
1230       W(I3%,L%) = W(I4%,L%)
1240       W(I4%,L%) = H1
1250     NEXT L%
1260 REM
```

```
1270     P1 = B(I4%,I4%)
1280     D3 = D3*P1
1290     B(I4%,I4%) = 1
1300     FOR L% = 1 TO N2%
1310       B(I4%,L%) = B(I4%,L%)/P1
1320     NEXT L%
1330     IF (N3%<1) THEN 1390
1340     FOR L% = 1 TO N3%
1350       W(I4%,L%) = W(I4%,L%)/P1
1360     NEXT L%
1370 REM
1380 REM
1390     FOR L1% = 1 TO N2%
1400       IF(L1% = I4%) THEN 1500
1410       T = B(L1%,I4%)
1420       B(L1%,14%) =0
1430       FOR L% = 1 TO N2%
1440         B(L1%,L%) = B(L1%,L%) - B(I4%,L%)*T
1450       NEXT L%
1460       IF (N3%<1) THEN 1500
1470       FOR L% = 1 TO N3%
1480         W(L1%,L%) = W(L1%,L%) - W(I4%,L%)*T
1490       NEXT L%
1500   NEXT L1%
1510 NEXT I%
1520 REM
1530 REM
1540 REM
1550 FOR I% = 1 TO N2%
1560   L% = N2% -I% +1
1570   IF(I2%(L%,1) = I2%(L%,2)) THEN 1650
1580   I3% = I2%(L%,1)
1590   I4% = I2%(L%,2)
1600   FOR K% = 1 TO N2%
1610     H1 = B(K%,I3%)
1620     B(K%,I3%) = B(K%,I4%)
1630     B(K%,I4%) = H1
1640   NEXT K%
1650 NEXT I%
1660 FOR K% = 1 TO N2%
1670   IF(I2%(K%,3)<>1) THEN 1850
1680 NEXT K%
1690 E1% = 0
1700 FOR I% = 1 TO N2%
1710   C1(I%) = W(I%,1)
1720 NEXT I%
1730 IF(I5% = 1) THEN 1870
1740 PRINT
1750 PRINT "    Matrix Inverse"
1760 FOR I%= 1 TO N2%
1770   FOR J% = 1 TO N2%
1780     PRINT USING A$; B(I%,J%);
1790   NEXT J%
1800 PRINT
1810 NEXT I%
1820 PRINT
1830 PRINT"Determinant = ";D3
1840 RETURN: REM IF INVERSE IS PRINTED
1850 E1% = 1
1860 PRINT"ERROR - Matrix is Singular"
1870 RETURN: REM From Gauss-Jordan Subroutine
1880 END
```

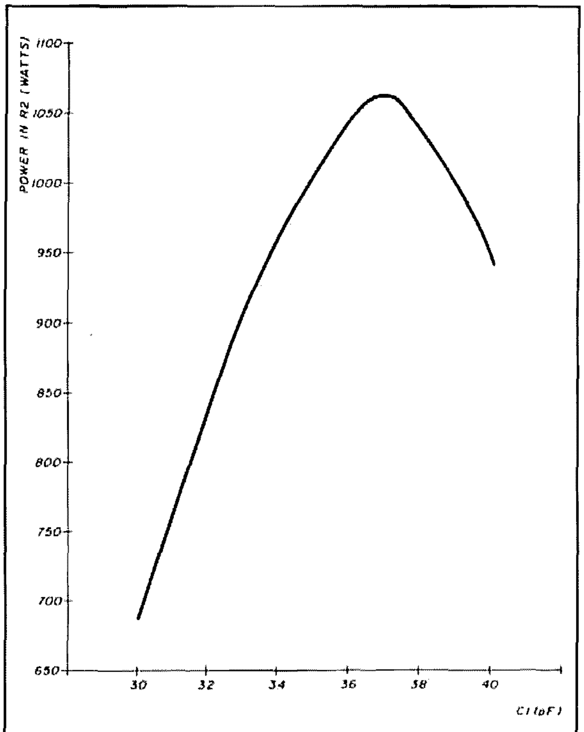


fig. 7. The results of "tuning" C1. The frequency was held constant and C1 was varied from 30 to 40 pF. The vertical scale is the power output $I_4^2 \cdot R2$.

amperes. Thus the calculated power output is about 1453 watts.

What stress is there on the rf amplifier components? The first thing we see is the voltage across C1. Common sense dictates that C1 should have a voltage rating of perhaps 4000 volts. The current through it is less than that flowing through C2. It doesn't seem to be a problem; there's less stress on that capacitor than there would be if the circuit had been a Pi-section. One normally assumes that the heaviest currents are locked up in the tank. But that's not so in this case; the heaviest rf current in the whole system is in the midsection of the filter! It's nearly 10 amperes for E = 3000 peak ac volts, and will be even higher for the 3500+ volts required for maximum legal output power.

Let's calculate the current through C4, the difference between I_3 and I_4. The vector difference is:

$$I_3 = -7.327 + j2.835$$
$$I_4 = 2.356 + j4.844$$
$$I_{C4} = I_3 - I_4 = -9.683 - j2.009$$
$$I_{C4}\ (scalar) = 9.89\ amperes$$

The voltage across C4 is:

$$I_{C4} \cdot (X_{C4}) = (9.89)\ (34.4) = 340\ volts.$$

Similar calculations can be made for all the other com-

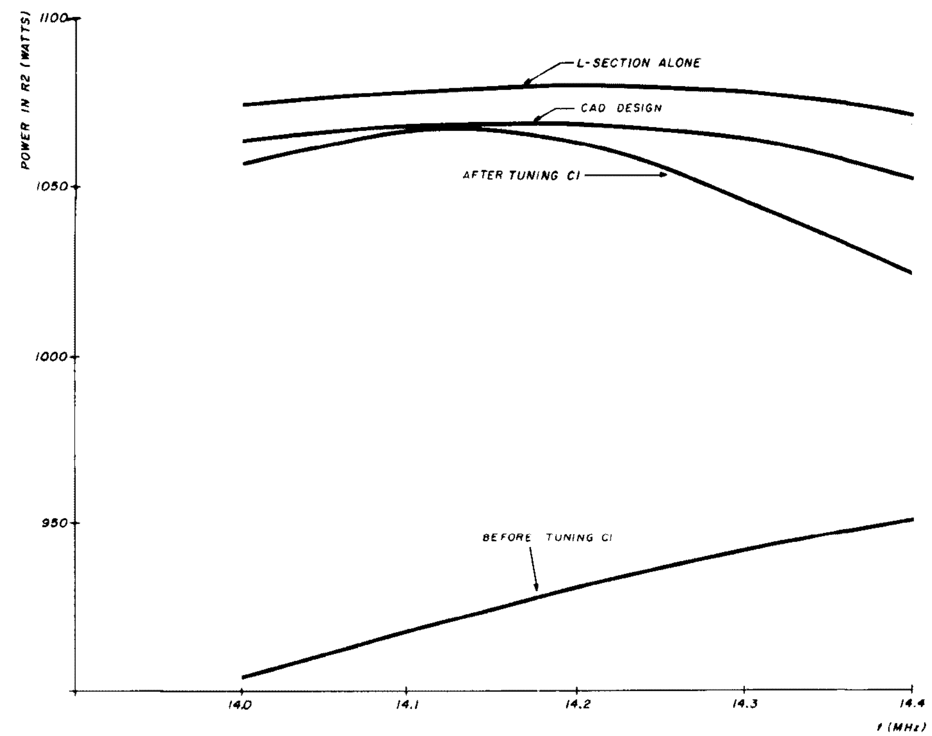


fig. 8. Power output over the 20-meter band using four different configurations. Note the difference between the "before and after tuning" data.

ponents. While "postage-stamp" capacitors could stand the voltage, they wouldn't tolerate the nearly 10-ampere current. Large transmitting-type or homemade capacitors must be used.

The capacitors for this amplifier are constructed from thin copper sheet, aluminum, and 0.030-inch Teflon™ sheet. For the 20-meter band, C2 and C4 are both approximately 300 pF. A homemade two-plate capacitor would measure only a few square inches in area; one side would be the amplifier chassis (or in this case, the bottom plate of the plug-in). All coils are fabricated from No. 10 copper wire. Had this been a Pi-section tank or even a Pi-L tank with the equivalent attenuation ratio of this design (without follow-up filter) the loaded Q would have had to be greater than 30, and the tank coil itself would have to be made of 1/4-inch diameter or larger copper tubing.

The same Gauss-Jordan routine may be used to calculate the attenuation at higher frequencies. Use the design values for components in the coefficients program, but change the frequency range and steps. The calculated attenuation at the second harmonic of this design is better than 50 dB; it's plotted in **fig. 10.**

All of the foregoing involves calculations with complex numbers. **Figure 11** contains BASIC routines that

```
2080 -302.92  0  302.92  0  0  0  0  3000  0
0  302.92  0  20.8  0  33.96  0  0  0  0
0  0  0  33.96  0  19.04  0  33.96  0  0
0  0  0  0  0  33.96  50  5.11  0  0

   REAL       IMAGINARY     MAGNITUDE      ANGLE

  0.61960     0.00354       0.61961        0.32768
  0.59526    -5.64561       5.67690      -83.98114
 -5.89132     3.42624       6.81519      149.81880
  2.70776     3.72465       4.60489       53.98348
```

fig. 9. Sample of the Gauss-Jordan program output. The numerical is the input matrix which contains all the coefficients, while the listing below represents the currents I_1 through I_4 in cartesian ($I_m \pm jI_m$) and polar coordinates (I/0).

can be used as they stand, included as subroutines that can be used as is, or be included as subroutines in a larger program. The solution in the figure is for I_{C4}.

conclusion

While the bulk of this work was done on a Tandy™ 2000 and the programs are written in MS-DOS BASIC, even the large matrix-handling program

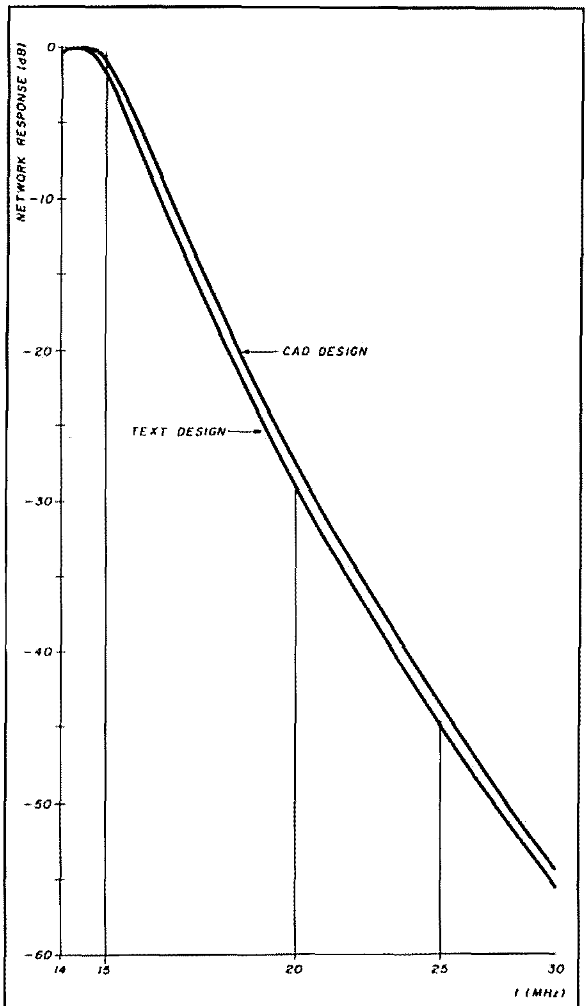


fig. 10. Calculated total network responses from 14.0 to 30.0 MHz. Both the text-designed and the CAD designed network responses are plotted.

represented by the Gauss-Jordan routine can be performed on the Commodore 64™ if the formatting lines (PRINT USING) and the integer symbols (%) are removed. It takes 30 to 45 seconds for the first solution to a four-current problem to appear on the C-64; the T-2000 requires only 6 seconds. With a compiled program the answers seem to appear instantaneously.

A few pertinent comments about using the Gauss-Jordan routine in this context are in order. The program will handle up to eight equations, but four seem to be the maximum number of equations one would want to try to solve. The execution time increases as approximately the cube of the number of equations, and there's a continuous rounding-off of the answers. While double-precision might help, the C-64 doesn't offer it, and I'd prefer to have this article remain useful to owners of the Commodore machines.

```
10 PRINT"                        COMPLEX ARITHMETIC:"
20 PRINT"                  ADD, SUBTRACT, MULTIPLY OR DIVIDE"
30 PRINT"                        TWO COMPLEX NUMBERS"
40 PRINT:
50 INPUT "ENTER REAL PART, FIRST NUMBER";RL1
60 INPUT "ENTER IMAGINARY PART, FIRST NUMBER";IM1
70 INPUT "ENTER REAL PART, SECOND NUMBER";RL2
80 INPUT "ENTER IMAGINARY PART, SECOND NUMBER";IM2:PRINT:
90 SIGN$= "-"
100 INPUT"ADD (1), SUBTRACT (2), MULTIPLY (3), OR DIVIDE (4)";Q:
110 ON Q GOTO 200, 300, 400, 600
120 GOTO 100
200 RL = RL1+RL2:IM=IM1+IM2:GOTO 630
300 RL=RL1-RL2:IM=IM1-IM2:GOTO 630
400 RL=RL1*RL2-(IM1*IM2):IM=IM1*RL2+RL1*IM2:GOTO 630
600 RL=(RL1*RL2+IM1*IM2)/(RL2^2+IM2^2)
610 IM=(IM1*RL2-RL1*IM2)/(RL2^2+IM2^2)
630 IF ABS(IM) = IM THEN SIGN$="+"
640 PRINT:PRINT"THE ANSWER IS   (";RL;" ";SIGN$;" J";ABS(IM)")"
650 PRINT:INPUT"ANY MORE? Y OR N";B$:PRINT
660 IF B$="Y" THEN 50: ELSE 670
670 END


RUN
                   COMPLEX ARITHMETIC:
            ADD, SUBTRACT, MULTIPLY OR DIVIDE
                   TWO COMPLEX NUMBERS

ENTER REAL PART, FIRST NUMBER? -7.327
ENTER IMAGINARY PART, FIRST NUMBER? 2.835
ENTER REAL PART, SECOND NUMBER? 2.356
ENTER IMAGINARY PART, SECOND NUMBER? 4.844

ADD (1), SUBTRACT (2), MULTIPLY (3), OR DIVIDE (4)? 2

THE ANSWER IS   (-9.683001  - J 2.009 )

ANY MORE? Y OR N? N
```

fig. 11. BASIC "four-factor" routines for the manipulation of two complex numbers. Useful as it stands, it is also useful for inclusion as steps in larger programs. The solution is for IC_4.

This article has defined a design problem, outlined the steps used to solve it with a PC, and produced a viable design that could probably be built with reasonable assurance that the final product would work. What began with an innocent question — "How is a no-tune amplifier designed?" — has ended with an amplifier actually under construction. Every design number and every program necessary to duplicate or extend that design have been presented here.

acknowledgments

I wish to thank Forrest Gehrke, K2BT, and Frank Chess, K3BN, for their useful suggestions and for their help in organizing this article.

references

1. *The Radio Amateur's Handbook*, American Radio Relay League, 54th edition, 19XX, page 54. (Note: the erroneous equation in the handbook has been corrected in this article.)
2. *The Radio Amateur's Handbook*, American Radio Relay League, 61st edition, 1984. Filter No. 8, Table 12, page 2-42.
3. *RF-CAD Electronics Design Program*, Joe Reisert, W1JR, and Gary Field, WA1GRC. Available from Ham Radio's Bookstore, Greenville, New Hampshire 03048, for $39.95 plus $3.50 shipping and handling.
4. *Basic Programs for Scientists and Engineers*, Alan R. Miller, SYBEX, 2021 Challenger Drive No. 100, Alameda, California 94501.

ham radio

lightning location and detection

Modern analog, digital techniques probe Nature's electrical generator

Lightning is an everyday occurrence, feared by some, accepted by most, but generally overlooked. Some 2000 thunderstorms are active at any moment throughout the world; this results in 100 lightning strokes every second of the year, or 40 million strokes per year in the United States alone.

Accurate detection of lightning is necessary for many reasons, including forest fire detection and control, power grid monitoring, flight planning, and public safety; NASA monitors lightning activity at various missile launch sites. Fortunately, technology now provides the means to accomplish these tasks with a high degree of accuracy.

North America has several extensive detection systems. Mexico, South Africa, Japan, Australia, Norway, Sweden, and recently China, have installed similar systems.

theory of detection

A lightning discharge to ground contains several large current surges or strokes. A *stepped leader* proceeds from the cloud to the ground in a series of short steps. After this leader reaches ground, a large return stroke travels rapidly back up the ionized path left by the leader. After a pause of 30 to 50 milliseconds, a *dart leader* usually forms; this is followed by one or more return strokes traveling upwards. Typically, a lightning stroke contains three, four, or more return strokes.

Until recently it was thought that a negative charge was transferred to ground during a lightning strike. But we now know that the incidence of positive charges increases as latitude increases towards the Earth's poles. Japanese researchers have also detected a large amount of positive lightning, which appears to emanate from the tops of clouds and be of higher current levels than negative lightning. There's still a considerable amount of research to be done in this area.

The current in return strokes attains levels of up to 40 kiloamps in 1 to 10 microseconds. The rise time and pulse width of this discharge form a distinctive waveform or signature that can be processed by the detection equipment to yield such data as azimuth bearings, real time, amplitude, polarity, and repetition of return strokes. When the data from two or more sites are triangulated and decoded by a central microprocessor, it's possible to pinpoint strike locations accurately to within 0.5 km at distances of 500 km.

detection system components

A typical detection system consists of two or more direction finders and a microcomputer; a block diagram of such a system is shown in **fig. 1**. Data is usually transmitted to a central *position analyzer* (PA) by means of dedicated telephone lines. Some installations use a polling system in which each direction finding site is polled. These systems require the use of asynchronous telephone lines. Recently, sites in remote areas (see **fig. 2**), especially in Third World countries, have used data transfer systems consisting of VHF and UHF radio links, using the principles of packet radio.

The electromagnetic field generated by a lightning stroke is sensed on two broadband orthogonal loop antennas and on an electric field, or "E" field, antenna. The latter consists of three flat plates stacked one above the other and separated by a few inches. The E field antenna senses the ambient noise level at a particular site to provide a comparison level for the loop antenna. The bandwidth of the antennas is 1 kHz to 1 MHz; this wide bandwidth is necessary to preserve the shape and polarity of the waveforms resulting from the lightning stroke.

Direction finding is done according to conventional techniques. The signal received by each loop is proportional to the lightning stroke's magnetic field multiplied by the cosine of the angle between the plane of the loop and the direction of the incoming signal.

By Bill Richardson, VY1CW, Site 20, Comp. 63, RR No. 1, Whitehorse, Yukon, Canada, Y1A 4Z6

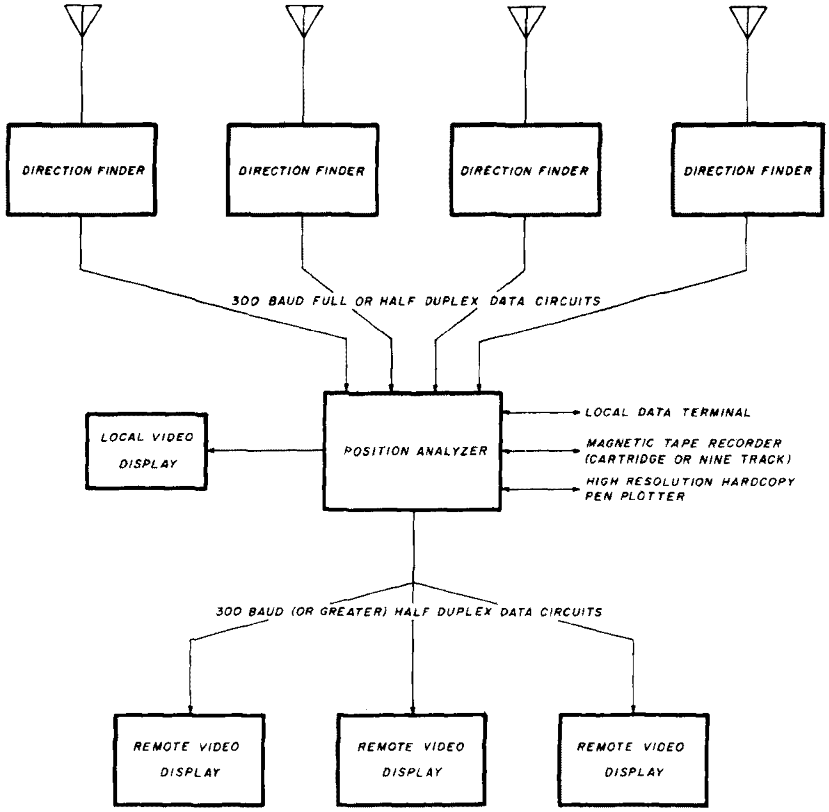


fig. 1. Block diagram of the basic LLP lightning locating system. In this example the position analyzer drives three remote display processors (RDP 80-02). In reality, the position analyzer may drive any number of remote display processors.

Therefore, the azimuthal bearing can be calculated from the signal strength ratio of the signals at the two loops.

The direction finding electronics are designed to respond to a waveform that's typical of a cloud-to-ground lightning stroke. Cloud-to-cloud lightning has an entirely different waveform and thus is ignored by the equipment.

These waveforms are identified by rise time, pulse width, and secondary peak structure. The rise time and bipolar shape requirements eliminate very distant lightning, because propagation delay increases the rise time of those waveforms. Ionospheric reflections of the signal don't pose a problem because they're typically inverted with respect to a ground wave signal. Some users employ both positive and negative stroke sensing.

The direction finder uses parallel low- and high-gain analog circuits. The waveshapes of near and distant lightning strokes are slightly different; therefore, the two analog circuits are set to switch automatically to values appropriate for subsequent strokes after the first stroke is detected. This provides maximum detection efficiency over a wide dynamic range.

Magnetic direction is determined at the time at which the radiation field of the return stroke reaches its peak; this point is attained while the return stroke is within approximately 300 feet of the ground. This provides an accurate indication of the ground contact point and eliminates errors that could be induced by multiple branch currents.

Detection efficiency is shown in fig. 3. The low efficiency at very close distances is caused by signals of sufficient magnitude to overrange the electronics. Peak efficiency is reached in the 20- to 250-km range and decreases beyond this because of lowering of signal amplitude and change of waveshape because of propagation delay.

As previously mentioned, accuracy can be within 0.5 to 1 kilometer at 300 kilometers, assuming enough direction finding sites are used for full area coverage. The electronics must be precisely aligned and calibrated — a very tedious procedure, I assure you. Alignment of the loop antennas must also be done

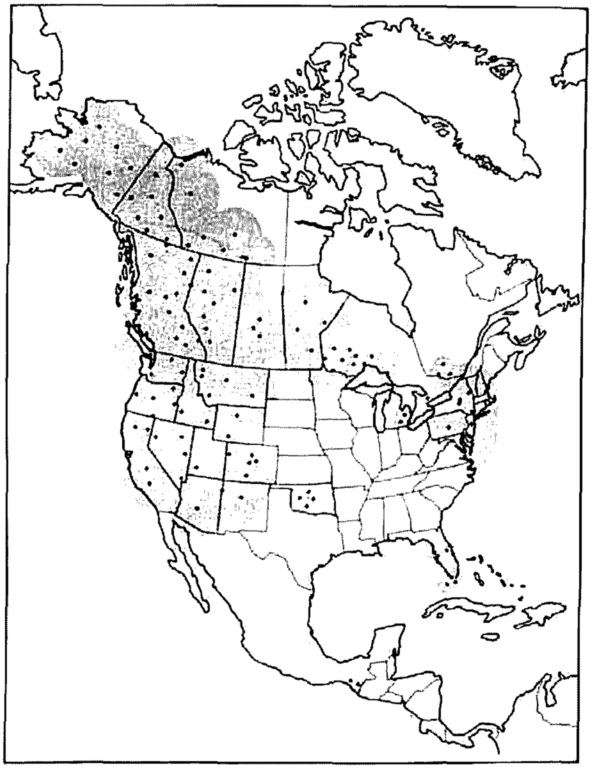


fig. 2. The solid dots show the locations of all LLP lightning direction finders installed in North America at the end of 1982. The shaded area represents the effective area covered by these systems.

accurately. The presently accepted method uses a shadow cast upon the antenna base plate by the north-south loop at precisely solar noon. Each direction finder has a built-in lightning simulator that can be set to duplicate acceptable and unacceptable lightning waveforms; this allows the system to be configured for peak detection efficiency.

system configuration

Sometimes a direction finder is used in a stand-alone mode, usually in conjunction with a weather radar. In this case, lightning data is plotted on an X-Y recorder. Clusters of vectors show the bearing to a storm cell; since vector length is proportional to the peak amplitude of the first return stroke, the length of the vectors can be translated into the distance to the strike.

The most common system configuration involves several direction finders reporting to a central position analyzer. Each direction finder has an integral microcomputer subsystem that digitizes and stores data for up to 14 return strokes. Each stroke is displayed on a front panel LED display. Time, angle to stroke, signal amplitude, polarity, and multiplicity of strokes are shown. This data is then transmitted to the position analyzer, a preprogrammed microcomputer system that automatically computes, maps, and records all lightning data. This data is then printed as hard copy and displayed on a CRT as lightning strikes superimposed on a map.

All computations and displays are done in real time. Data can be stored and replayed to determine storm

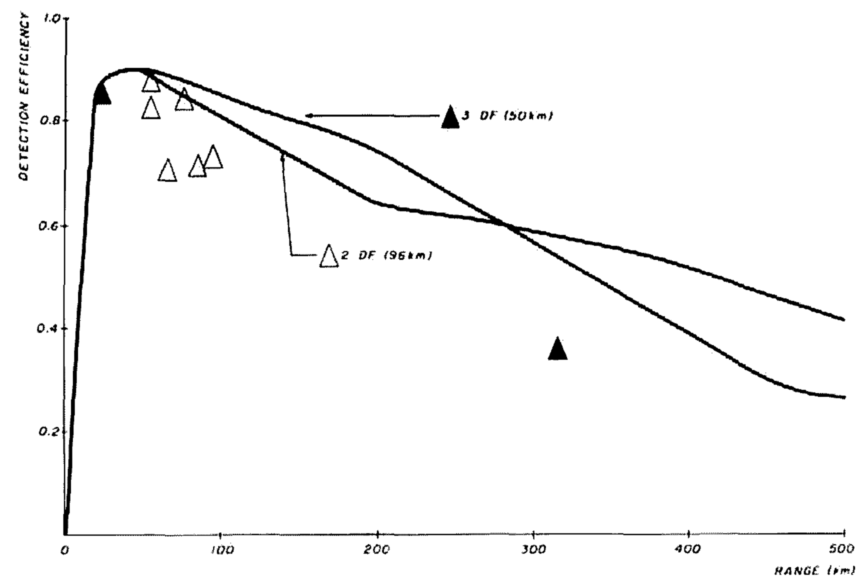


fig. 3. Detection efficiency versus range for two medium-gain LLP networks.

direction, intensity, growth, and decay. For example, a program can be selected to periodically delete strike locations older than a preset time interval, with various colors assigned to strikes occurring within different time periods. This accumulated data can then be replayed at an accelerated rate to display the storm's life cycle.

communications system

Time has shown that the communications links are the greatest source of problems in the system. Two basic systems — the "star" and the polled — are in common use. The polled system stores data until the PA requests it. In the star system, the simpler of the two, remote sites are connected to the PA via dedicated half-duplex telephone lines, and data is transmitted to the PA in real time. Though costs are higher with this system because of the dedicated line, which is in constant use, the system's simplicity often compensates for its higher costs.

In the past two years, many Third World countries have installed lightning detection equipment. Because standard communications links are almost non-existent in many of these areas, UHF radio links using packet radio have been used; to date, the results are very encouraging. Many such UHF links will be installed in northern and otherwise remote areas of North America over the coming year. This will not only allow new areas to be covered, but also decrease communications costs.

The manufacturer of the equipment described in this article has introduced a simplified direction finder which can be operated on solar power. This feature will help increases coverage, since ac power sources will no longer be required.

I'll be working closely with the manufacturer to experiment with the possibility of relaying data by radio transmissions reflected from the ionized trails created by the lightning stroke, much like the method used in meteor scatter communications.

conclusion

Space limits the depth of description of lightning detection equipment and techniques, but the foregoing should provide a general overview of this new technology. Because the field is still in its infancy, systems are especially challenging. Much research and development can and is being done by field personnel.

acknowledgements

My thanks to Leon Byerly of Lightning Location and Protection, 1001 South Euclid Avenue, Tuscon, Arizona 85719, for his help in preparation of this article.

ham radio

designing a microwave amplifier

Step-by-step procedure starts with specs, ends with results

Most people who aren't familiar with microwave technology regard microwave engineering as somewhat mysterious. Nothing could be further from the truth.

Often this opinion stems simply from limited knowledge of the subject, from a misconception that all power transmission requires a waveguide or "plumbing," or from a general lack of interest. Knowing that in microwave design, circuit performance is exceptionally dependent on layout* and understanding the mathematics associated with field theory and the use of distributed parameters for impedance matching, it's possible to conclude that microwave engineering is an arcane art limited to the very few. *Not so!*

S-parameters

Manufacturers of microwave electronic components, namely transistors, characterize these devices according to scattering parameters known also as "S" parameters. S parameters are simply voltage reflection coefficients that possess both magnitude and phase. Consider a 25-ohm resistor at the end of a 50-ohm transmission line (**fig. 1**). The reflection coefficient of the 25-ohm load is computed as follows:

$$\Gamma = \frac{Z_L - Z0}{Z_L + Z0} = \frac{25 - 50}{25 + 50} = \frac{-25}{75} = \frac{-1}{3} \qquad (1)$$

Γ can be complex and is simply a reflection coefficient; that's what an S parameter is — nothing more than a reflection coefficient. The S parameters are measured values and give an indication as to the performance of the device, and are generally measured in a 50-ohm system. It's more practical to construct a 50-ohm termination than to rely upon open circuits and short circuits and attempt to characterize a device with "Y" or "Z" parameters. The four S parameters specified are S11, S12, S21, and S22 (see **fig. 2**).

$$S11 = \frac{b1}{a1} \textit{ with } a2 = 0 \textit{ and} \qquad (2)$$

is a measure of input impedance

$$S22 = \frac{b2}{a2} \textit{ with } a1 = 0 \textit{ and}$$

is a measure of output impedance

$$S21 = \frac{b2}{a1} \textit{ with } a2 = 0 \textit{ and is a measure of forward power gain}$$

$$S12 = \frac{b1}{a2} \textit{ with } a1 = 0 \textit{ and}$$

is a measure of reverse power gain

S parameters are simply related to power gain and mismatch loss, quantities which are often of more interest than the corresponding voltage functions.

$$|S11|^2 = \frac{\text{Power reflected from network input}}{\text{Power incident on the network input}}$$

$$|S22|^2 = \frac{\text{Power reflected from network output}}{\text{Power incident on the network output}}$$

$$|S21|^2 = \frac{\text{Power delivered to a Z0 load}}{\text{Power available from Z0 source}}$$

$$|S12|^2 = \frac{\text{Reverse transducer power gain}}{\text{with Z0 load and source}}$$

It's important to understand that S parameters are measured parameters and give the designer a real-world indication as to how the particular transistor will work. Generally, a designer's most important considerations are power gain, noise figure, stability, biasing, and a necessary matching structure for reasonable VSWR.

A transistor is a bilateral device, with the amount of bilateral interaction defined by S12. Analyzing the performance of an amplifier operating as a bilateral device is a tedious process, and one has to resort to the use of computers and commercially available programs

*i.e., you don't wire a 4-GHz amplifier the same way you'd wire a car. Consider that a piece of No. 26 wire measuring 0.050 inches long represents an impedance of j25 ohms at 4.0 GHz. This would introduce a voltage SWR (mismatch) of 1.63:1, with 5.8 percent of the power reflected back to the generator should this wire be connected in series in a 50-ohm system.

By Stanley J. Domanski, ex-WA1WSD, 3 Lessard Street, Nashua, New Hampshire 03060

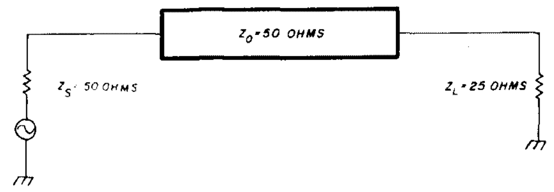


fig. 1. Mismatch occurs when 25-ohm load is inserted directly in 50-ohm system.

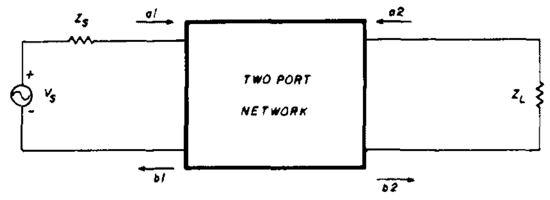


fig. 2. Two-port network used to define S parameters.

such as Super-Compact,** a rather powerful microwave circuit design optimization program. For the purpose of illustration, we will assume a unilateral device (S12 = 0.0).

using the data sheet

Suppose someone gives you several NEC NE388 GaAsFET transistors and a data sheet, then asks you to design an amplifier that's to operate at 3 GHz. Approximately how much gain should you expect to achieve? What would the input and output matching network look like?

Start by reviewing the data sheet for the FETs. (For this design, noise figure is not a consideration.) The load impedance and source impedance are both 50 ohms. The device is a GaAsFET. You'll also notice that the S parameters are specified at V_{DS} = 3.0 volts and I_D = 10 mA. Therefore, for the matching network to be effective and for the gain calibration to be meaningful, the device must be biased at these values of V_{DS} and I_D. Try to get a feeling for maximum usable gain, i.e. the Gain Transducer Unilateral (GTU). (This assumes a unilateral device where S12 = 0 and a matched source and load condition exists.) This was derived from the more general equation for GT (Gain Transducer) under the conditions specified above.

$$GTU\ max = \frac{1}{1 - |S11|^2} \bullet |S21|^2 \bullet \frac{1}{1 - |S22|^2} \qquad (3)$$

At 3000 MHz,

$$S11 = 0.892\ \underline{|-63^\circ}, \ S21 = 2.368\ \underline{|133^\circ} \qquad (4)$$

$$S22 = 0.772\ \underline{|-41^\circ}, \ S12 = 0.034\ \underline{|52^\circ}$$

$$GTU = \frac{1}{1 - (0.892)^2} \bullet \frac{(2.368)^2}{1} \bullet \qquad (5)$$

$$\frac{1}{1 - (0.772)^2} = (4.893) \bullet (5.607) \bullet (2.475) =$$

$$67.90 \text{ or } 10 \log GTU = 18.32 \text{ dB}$$

This computation is consistent with the data sheet. Notice that in addition to providing a table of S parameters for the packaged devices, S parameters are given for NE388 chips as well, and the S parameter data is listed for frequencies from 2 to 10 GHz in 0.5-GHz step increments. Note that S11 and S12 are both capacitive, but become more inductive as frequency increases.

S11 represents approximately 10 −j80 ohms and S22 represents approximately 50 − j120 ohms. For optimum performance and power gain, the transistor's input and output impedances should be matched to 50 ohms.

One suitable way of constructing this amplifier is a technique called *microstrip*. Microstrip possesses transmission line characteristics and is essentially just conductive runs over a conducting ground plane, with an intermediate substrate in between.

matching procedure

The idea is to "move" S22 and S11 to the 50-ohm center of the Smith Chart (**fig. 3**). In both cases, this is done by rotating on a length of transmission to the constant conductance circle that is coincident with the center of the Smith Chart or the 50-ohm location and then adding a parallel capacitor of the appropriate size. For the S22 match, a length of line 0.194λ + 0.055λ = 0.249λ is used to rotate to constant conductance circle coincident with 50 ohms; for S11 the length of line is:
0.163λ + 0.038λ = 0.201λ.
Y(S22) = 2.4 = Y/B0
Since our transmission line characteristic is Z0 and is 50 ohms,

B0 = 1/Z0 = 1/50 or 0.02
Y = y•B0 = 2.4 • 0.02 = 0.048 mhos
Y = 2πfC mhos

$$C = \frac{Y}{2\pi f} = \frac{0.048}{2\pi \times 3 \times 10^9} = 2.54 \times 10^{-12} \text{ farads}$$

A 2.54 • 10^{-12}F (2.54 pF) capacitor shunting the transmission line to ground will add enough susceptance to complete the output match to 50 ohms.

A similar procedure is used to match the input to 50 ohms.

**A product of Compact Software, 483 McLean Boulevard, Paterson, New Jersey 07504.

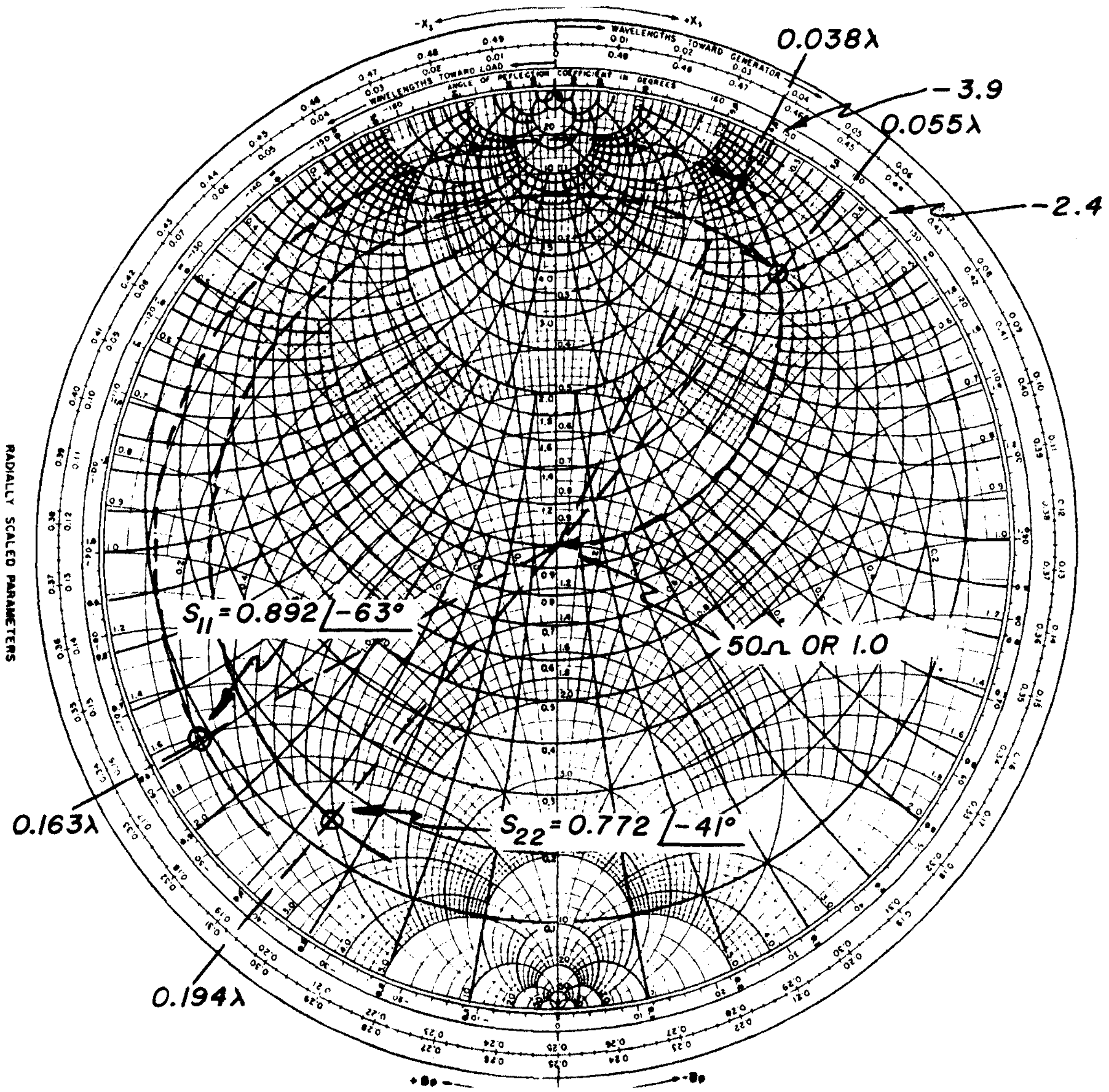


fig. 3. GaAsFET, NE388 matching using Smith Chart.

$$y(S11) = \frac{y}{BO} = 3.9 \text{ mhos}$$

$$Y = y \bullet BO \qquad (7)$$

$$= 3.9 \times 0.02 = 0.078 \text{ mhos}$$

$$Y = 2\pi fc \text{ mhos} \quad C = \frac{Y}{2\pi f} = \frac{0.078}{2\pi \times 3 \times 10^9} \qquad (8)$$

$$= 4.138 \times 10^{-12} \text{ Farad}$$

A 4.138×10^{-12}F (4.138 pF) capacitor shunting the transmission line to ground will add enough susceptance to complete the input match to 50 ohms. Thus far, what we have represented is shown schematically in **fig. 4**.

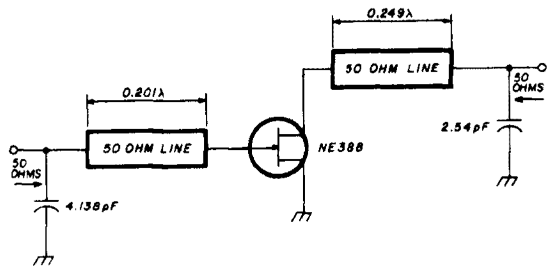


fig. 4. Component values determined for GaAsFET input/output match.

microstrip components used

The microstrip substrate is a teflon material with a dielectric constant of 10.0. The distributed characteristics of microstrip will be utilized to synthesize the 50-ohm transmission line and shunt capacitors. The lengths of the input and output transmission lines are 0.201λ, and 0.249λ, respectively.

The equation relating frequency and wavelength is c = fλ, where c is the velocity of light and is $3 \cdot 10^{10}$ cm/sec. In air, the wavelength of a 3-GHz signal is

$$\lambda = \frac{c}{f} = \frac{3 \times 10^{10}\ cm\ /\ sec}{3 \times 10^{9}\ Hz} = 10\ cm \qquad \textbf{(9)}$$

or approximately 3.937 inches. The effective wavelength in a material other than free space is the wavelength in free space divided by the square root of the dielectric constant. For a substrate whose dielectric constant is 10.0, the effective wavelength is

$$\frac{\lambda}{\sqrt{\epsilon_r}} = \frac{10.0\ cm}{\sqrt{10}} = 3.16\ cm \qquad \textbf{(10)}$$

or 1.2449 inches. The length of the input matching section is 0.201λ and the length of the output matching section is 0.249λ. This in air would represent (0.201λ) (3.937 inches/λ) = 0.7913 inches and (0.249λ) (3.937 inches/λ) = 0.9803 inches.

In a substrate with a dielectric constant of 10.0, the real lengths of the input and output become (0.7913 inches) (0.3162) = 0.2502 inches and (0.9803 inches) (0.3162) = 0.3099 inches, respectively.

The characteristic impedance of microstrip, Z0 is:

$$\frac{h}{w} \times 377 \times \frac{1}{\sqrt{\epsilon_r}} \qquad \textbf{(11)}$$

The impedance selected for our line is 50 ohms and ϵ_2 = 10.0. The substrate thickness is 0.020 inches. Solving for W:

$$\omega = \frac{377 \times h}{Z0 \times \sqrt{\epsilon_2}} = \frac{377 \times 0.020}{50 \times \sqrt{10}} = 0.0476\ in \qquad \textbf{(12)}$$

Thus the width of a conductor whose characteristic impedance is 50 ohms on a substrate whose thickness is 0.020 inches, with a dielectric constant of 10.0, is 0.0476 inches. The original schematic takes on a new aspect — dimensions (see **fig. 5**).

The input capacitance of 4.138 pF and output capacitance of 2.54 pF will be synthesized using microstrip techniques. Generally, if the width of a segment is twice as wide as the length, the section looks like a shunt capacitor.

The capacitance of a parallel plate capacitor is:

$$C\ (pF) = \frac{0.224\ A\ \epsilon_r}{d} \qquad \textbf{(13)}$$

where:

A is the area of the plate in square inches
d is the separation of the plates in inches
ϵ_r is the dielectric constant

Solving for A:

$$A1 = \frac{(C1)\ (d)}{(0.224)\ (\epsilon_r)} = \frac{(4.138)\ (0.020)}{(0.224)\ (10)} \qquad \textbf{(14)}$$

$$A1 = 0.0369\ in^2$$

Similarly:

$$A2 = \frac{(C2)\ (d)}{(0.224)\ (\epsilon_r)} = \frac{(2.54)\ (0.020)}{(0.224)\ (10)} \qquad \textbf{(15)}$$

$$= 0.0227 in^2$$

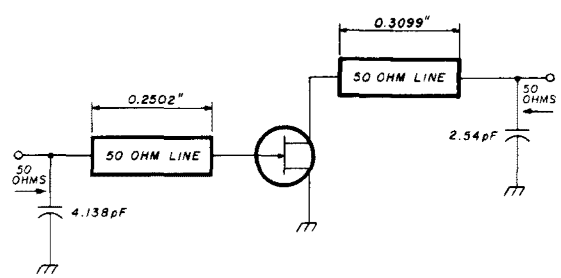


fig. 5. Transmission line physical parameters determined from requirements.

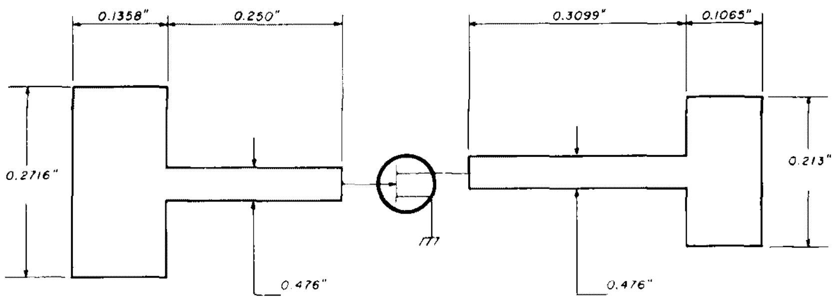


fig. 6. Input and output matching structure dimensions.

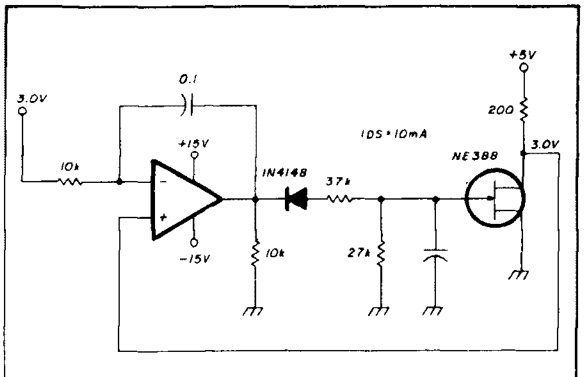


fig. 7. Feedback network improves amplifiers temperature-handling capability.

The circuit now takes on the appearance of that shown in **fig. 7.**

The basic radio frequency input and output matching structure is now defined.

This matching structure was based on S parameters which were stated for a given V_{DS} and I_{DS}. A GaAs-FET device is a transconductance device; this simply means that it's a voltage-controlled current source.

feedback and biasing

This brings up the means by which the devices should be biased. A quick glance at the data sheet reveals the NE388 will require a V_{GS} of approximately -3.0 volts to maintain a $V_{DS} = 3.0$ volts and $I_{DS} =$ 10.0 milliamperes. But the V_{GS} necessary to maintain

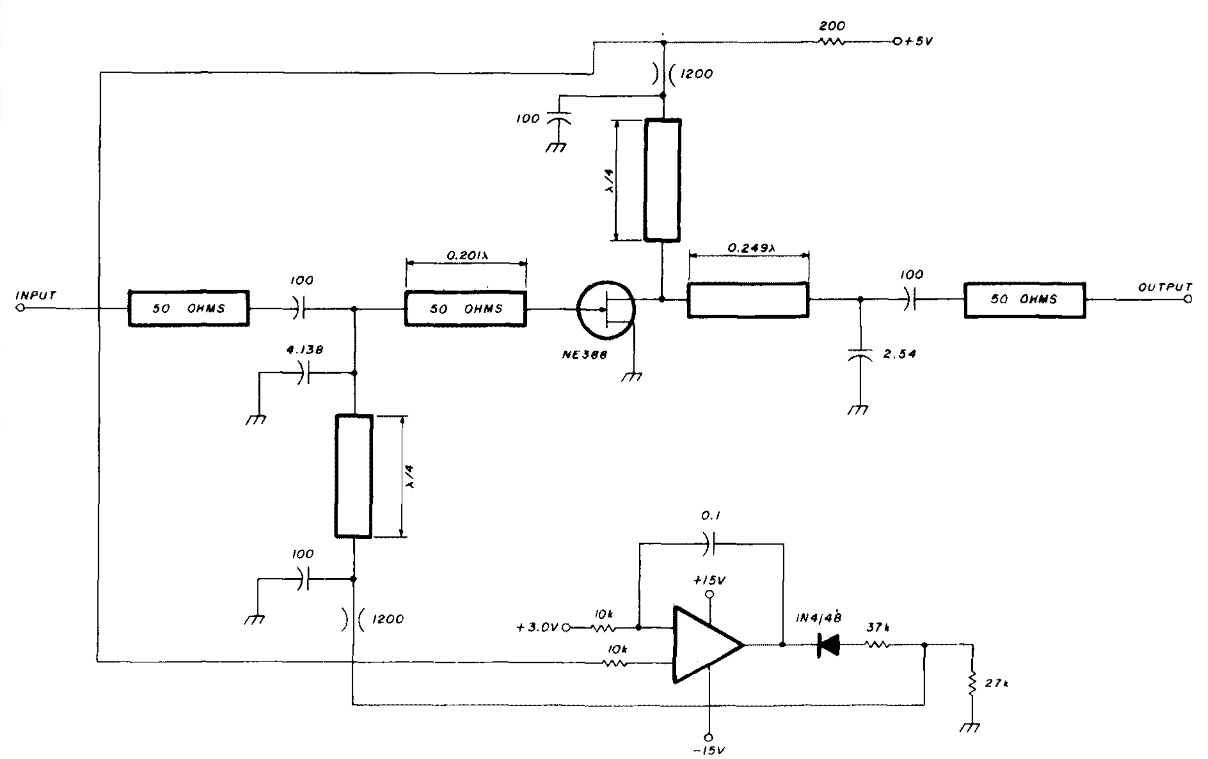


fig. 8. Complete distributed and lumped component 3GHz amplifier circuit.

We wish to make the width of the section twice as wide as the length. Therefore,

$$2\ell^2 = A1 \quad \ell^2 = \frac{A1}{2} \tag{16}$$

$$\ell = \sqrt{\frac{A1}{2}} = \sqrt{\frac{0.0369}{2}} = 0.1358\ in$$

Similarly:

$$\ell^2 = \frac{A2}{2} \quad \ell = \tag{17}$$

$$\sqrt{\frac{A2}{2}} = \sqrt{\frac{0.0227}{2}} = 0.1065\ in$$

these aforementioned bias conditions can vary between -2.5 to -3.5 volts — a production nightmare, especially if the unit must operate between -55 and $+70$ degrees C. Solution: use a servo — i.e., a feedback circuit!

I suggest the circuit shown in **fig. 8** because I know it works well over a wide range of temperatures. The microwave matching network components are left out for simplicity.

The three critical items in this circuit are the stability of the $+5.0$ volts, the accuracy and stability of the

200-ohm resistor, and the 3.0-volt reference. The diode prevents the possibility of a positive voltage being applied to the gate. A positive voltage on the gate without considerable current limiting would damage the device.

The voltage divider consisting of the 37.4-k and 27.4-k resistors prevent the gate to source voltage from exceeding -8.0 volts during initial turn-on. The dc bias, namely the V_{DS} and V_{GS} is applied to the NE388 through the use of high-impedance, quarter-wave, short-circuited stubs. The short circuit at 3 GHz is accomplished by wire-bonding the end of the stub to a 100-pF chip capacitor that is connected to ground. Remember, a quarter-wave long transmission line short-circuited on one end looks like an open circuit on the other. The design procedure results in the realizable 3-GHz amplifier circuit shown in **fig. 9**.

ham radio

simple VHF/UHF multiple quarter-wave filters

Individual or cascaded sections provide required harmonic suppression

Thanks to the simplicity of its design, construction, and alignment, the half-wave, low-pass configuration[1] is one of the most popular transmitter filters at VHF and UHF.

The half-wave filter, consisting of two pi sections of inductors and capacitors in cascade (see **fig. 1**), is so named because the output signal is delayed one-half wavelength* at the highest design pass frequency. Just as in the case of a half-wavelength transmission line, the same impedance seen at the output terminals of the half-wave filter is presented to the amplifier at the filter input terminals. The principal use of this filter is simply to reduce transmitter harmonics.

This article shows how to calculate the values for quarter, half, three-quarter, and full-wave VHF/UHF filters. The effects of varying the circuit Q will be explored. If reasonable construction techniques are used, a guaranteed minimum level of attenuation can be expected for transmitter harmonics, even without using test equipment for alignment. Multisection filters have been constructed using lumped constants for the 6, 2, and 1-1/4 meter bands, with very good agreement to theoretical values. Microstrip quarter-wave and half-wave filters have also been built for the 432- and 1296-MHz bands. Half-wave filters for the hf band can be constructed using standard values contained in tables [2,3] without need for adjustments. At VHF however, construction techniques dictate that the filter actually be adjusted for best performance, usually with a grid-dip meter. At UHF, construction practices require the use of a reproducible pattern found in microstripline form. If the same printed circuit board type and thickness are used, similar performance can be assured without any alignment.

*The signal is delayed 180 degrees or the equivalent that would occur in a properly terminated half-wave *electrical* transmission line. – Ed.

reducing interference

There are many reasons — legal, environmental, and ethical — for reducing spurious and harmonic emissions. According to Part 97.73 of the FCC Rules and Regulations for the Amateur, "Spurious emissions (including harmonics) must be 40 dB below the carrier power for a transmitter operating below 30 MHz. If the transmitter has an output power of 5 watts or less, the spurious at the transmitter output need only be reduced by 30 dB. Harmonics for transmitters and power amplifiers operating in the 30- to 235-MHz range must be reduced 60 dB below the carrier level. Transmitters below 25 watts output need to attenuate harmonics by only 40 dB."

With a typical amplifier, the second harmonic is only 20 to 30 dB down and the third harmonic is 30 to 40 dB down from the fundamental carrier (**fig. 2**). When the harmonic content of a transmitter, exciter, or oscillator is monitored on a spectrum analyzer or sensitive receiver, the carrier should be "notched-out" as much as possible. The input mixer of the spectrum analyzer or the front end of a receiver is prone to generate harmonic energy when driven by a large carrier signal, and will indicate greater harmonic energy than is actually present. The common method of determining if the amplitude of a transmitter harmonic is real is to place an attenuator in front of the spectrum analyzer. If the harmonic drops by an amount greater than the value of the inserted attenuation, then the harmonic was generated in the mixer of the analyzer.

In a balanced (i.e., push-pull) amplifier design, the second harmonic power will typically be down better than 30 dB (depending on circuit balance). The odd order (third, fifth) harmonics, however, will remain high (−20 dB). Thus the principal filtering response

By Ernie Franke, WA2EWT, 10484 138th Street, Largo, Florida 33544

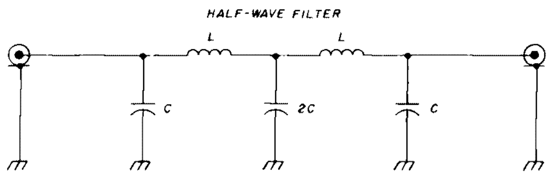


fig. 1 The half-wave filter is popular because of the simplicity of its calculation, construction, and adjustment.

$$X_L = 2\pi fL = 50 \text{ ohm}, \quad X_C = 1 / 2\pi fC = 50 \text{ ohm} \quad (1)$$

The value of inductance and capacitance is then simply computed as

$$L = 50 / 2\pi f \text{ henries}, \; C = 1 / 2\pi f (50) \text{ farads} \quad (2)$$

where f is the highest design pass frequency in Hz. The values of L and C may be directly scaled up or down, depending on the source and load impedances. The basic quarter-wave pi network may be considered

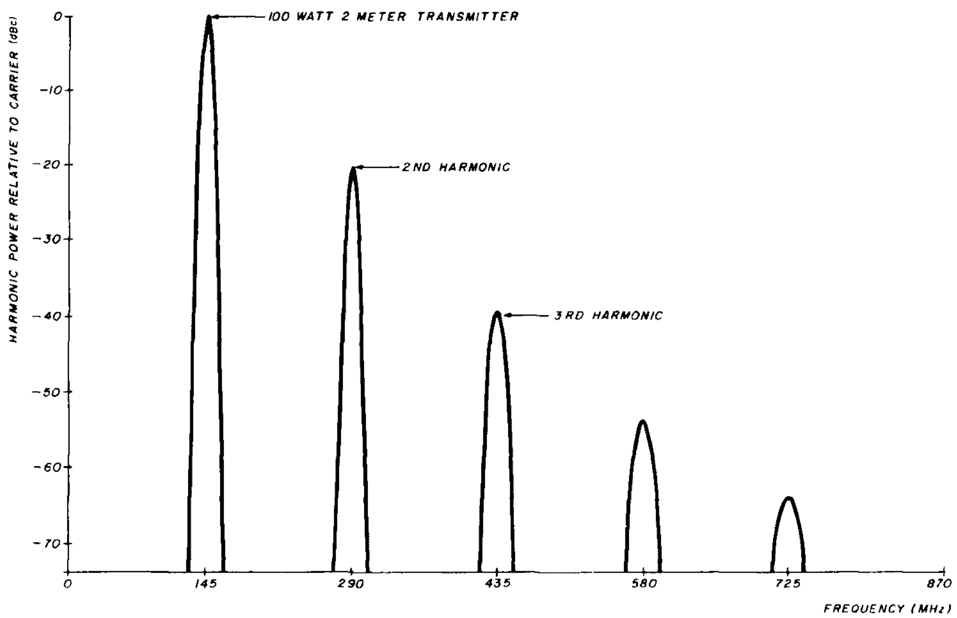


fig. 2. Typical power spectrum from a 2-meter, 100-watt transistor power amplifier.

required by a low-pass filter on a balanced amplifier will be out at the third harmonic.

design

The basic building block of the multiple quarter-wave filter is the quarter-wave pi network shown in **fig. 3**. Cascading of these quarter-wave networks forms the half-wave, three-quarter wave, and full-wave filters, providing the theoretical frequency responses shown in **fig. 4**. Experimental results for various section VHF filters are also shown. As each section is added, the slope of the stop-band becomes steeper. The responses of several filters constructed using lumped constants are shown to agree reasonably well with the theoretical values.

The inductive and capacitive reactances of the quarter-wave filter are chosen to be equal to the source and load impedances, typically 50 ohms.

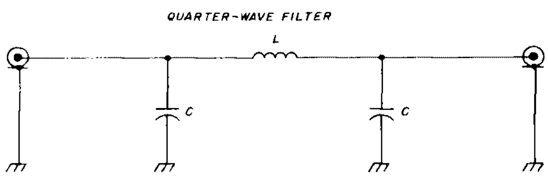


fig. 3. The quarter-wave filter, composed of two L-networks, represents the basic building block.

as two L-networks connected together, **fig. 5**. The Q of each L-network is given as

$$Q1 = R1 / X_{C1} = 2\pi f \, C1 \, R1 \text{ and} \quad (3)$$
$$Q2 = R2 / X_{C2} = 2\pi f \, C2 \, R2$$

The total circuit Q is equal[4] to the sum of the individual Q's:

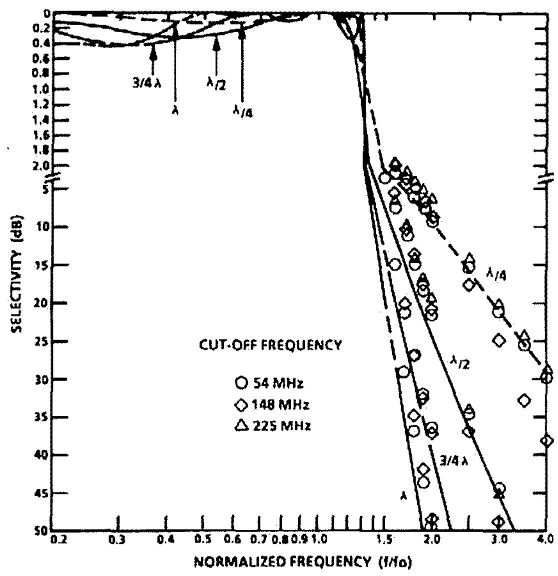


fig. 4. Frequency response of the quarter-, half-, three-quarter, and full-wave filters.

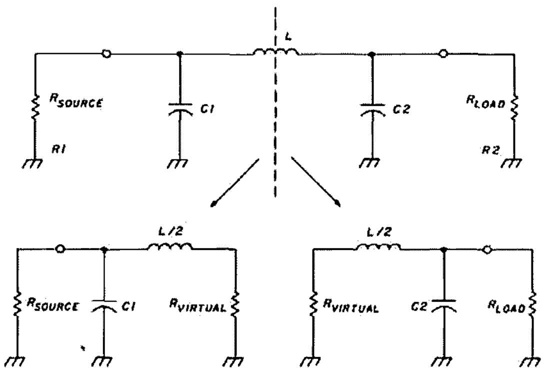


fig. 5. The basic building block may be split into two L matching networks.

$$Q_T = Q1 + Q2 \tag{4}$$

and because of symmetry,

$$Q_T = 2Q1 \tag{5}$$

The reactance, X_L, of the inductor and the reactance, X_c, of each capacitor is

$$X_L = R1Q_T / [(Q_T 2 / 4) + 1] = 2R1Q1 / (Q1^2 + 1) = 2\pi fL; \quad L = R1Q1 / \pi f (Q1^2 + 1) \tag{6}$$

$$X_c = R1 / Q1; \; C = Q1 / R1\, 2\pi f \tag{7}$$

For a 50-ohm source and load,

$$L = \frac{50Q1}{\pi f (Q1^2 + 1)} \text{ and } C = \frac{Q1}{50 (2\pi f)} \tag{8}$$

In an L-network for a Q of 1, which yields an overall network Q_T of 2, the value of the inductance and each capacitance is

$$L = 50 (1) / \pi f (2) = 50 / 2\pi f, \tag{9}$$

$$C = (1) / 50 (2\pi f) = 1 / 50 (2\pi f)$$

The filter for several values of overall Q_T have been calculated using the elements calculated according to

$$L = R1Q_T / [(Q_T^2 / 4) + 1](2\pi f) \tag{10}$$

$$C = Q_T / R1\, 4\pi f$$

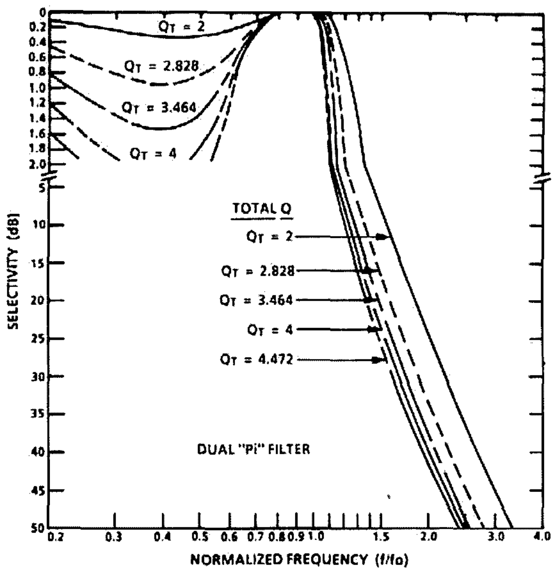


fig. 6. The overall loaded Q of the filter may be increased to yield greater harmonic attenuation — at the expense of greater in-band amplitude ripple.

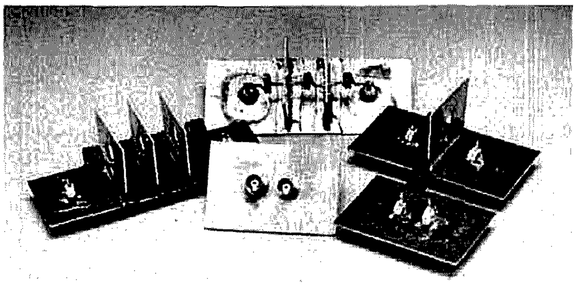


fig. 7. Several quarter-, half-, three-quarter, and full-wave filters were constructed using scrap PC boards.

Table 1. Basic quarter-wave filter elements.

shunt capacitor		series inductor			
frequency	value	value	wire size	number turns	diameter
54 MHz	59 pF	147 nH	No. 14	4T	3/8 inch ID
148 MHz	22 pF	54 nH	No. 14	2T	1/4 inch ID
25 MHz	14 pF	35 nH	No. 14	1 inch high, 1/2 inch wide hairpin	

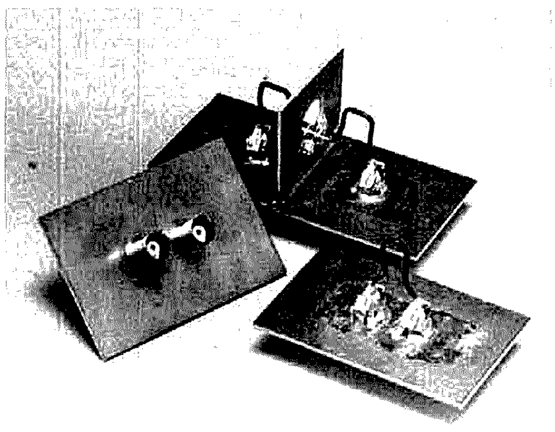


fig. 8. At 220 MHz, the inductors take the shape of hairpin inductors.

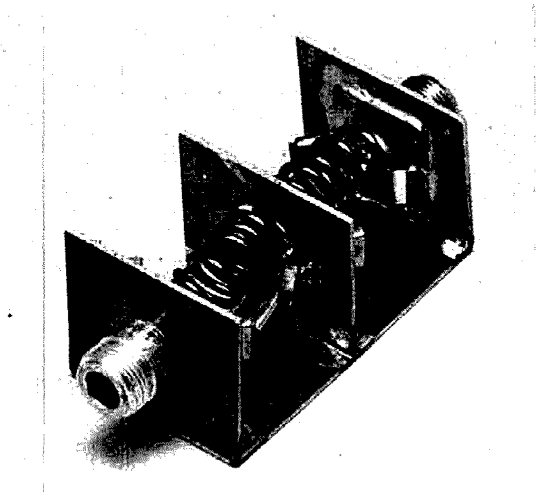


fig. 9. High-power filters require larger size wire and larger capacitors.

The response of the quarter-wave filter for various values of total Q is plotted in **fig. 6**.

The simple quarter-wave pi section may be thought of as consisting of two L-section matching networks, with the first L-network transforming the source impedance of 50 ohms to a lower value and the second L-section transforming this virtual impedance back to 50 ohms. If the network has a Q of 1, the virtual impedance will be 25 ohms. The value of the virtual impedance depends on the circuit Q:

$$R_{virtual} = R_{source} / (Q1^2 + 1) \qquad (11)$$

The half-wave filter in **fig. 1** is formed by cascading two quarter-wave filters. The shunt capacitors at the junction of the two quarter-wave filters may be combined into a single capacitor. As the power through the filter is increased, it is better to use two capacitors to support the increased current.

construction

At VHF and UHF, the ground plane of a filter must be given careful thought (see **figs. 7** and **8** and **table 1**). Appreciable inductance in the ground path will cause extra resonances to appear, especially at the higher frequencies. Harmonic energy must not be allowed to "sneak around" the filter due to extraneous ground paths. The capacitors must also have low-inductance leads. Metal-clad, uncased precision mica and teflon capacitors[5,6] can be used at VHF to minimize this lead inductance by soldering the case directly to the ground plane. The coils[7,8] are self-supporting

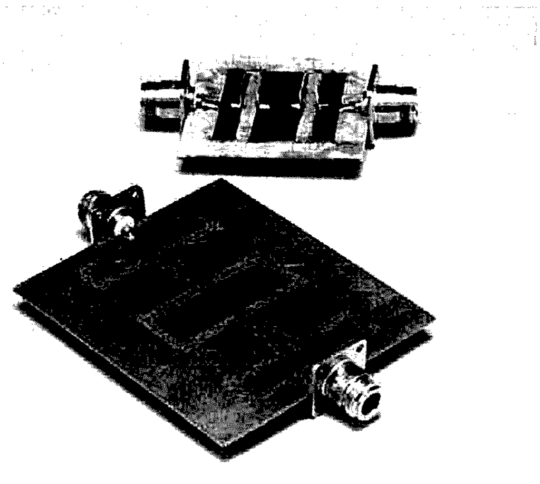


fig. 10. Microstripline filters use either printed or hairpin inductors.

and wound with No. 14 formvar-covered wire. Higher power filters (**fig. 9**) require larger wire and more capacitors in parallel to handle the increased current.

432- and 1296-MHz quarter-wave filters can use a microstripline structure with either (**fig. 10**) printed or hair pin inductors. The lumped capacitors are shaped to have minimal series inductance and the pc inductors are formed by "necking down" the center conductor (0.025-inch wide and 1.225 inches long at 450 MHz and 0.424 inches long at 1.3 GHz.) Type N launchers were added at the edge of the printed circuit boards.[9] **Table 2** includes dimensions for these same two filters using hair-pin inductors. The experimental results, comparing hairpin inductors with etched printed lines, are shown in **fig. 11**.

adjustment

Because most hams don't have sweep generators for checking filter response at the second, third, and fourth harmonics, it's best to construct simple VHF filters using lumped elements, which can be readily adjusted using a grid-dip meter. If reasonable construction practices are followed, one can expect a certain minimum guaranteed performance at the harmonics because adjustments have been made to ensure minimum loss at the design frequency. The simple quarter-wave filter is adjusted to the design frequency by shorting out a capacitor at either end of the pi network and adjusting the inductor for resonance, with the source and load impedances removed, as shown in **fig. 12A**. This effectively forms a parallel resonant circuit with C and L. The short circuit should be placed close to the common ground plane to decrease series inductance. Using a grid-dip meter, adjust the coil to resonate with the open capacitor at the design frequency. Adjust the half-wave filter in a similar manner by shorting the "double-value" capacitor and then adjusting each coil to resonance, as in **fig. 12B**. Adjust the three-quarter wave filter in a similar manner, as shown in **fig. 12C**. The center coil is simply adjusted to physically resemble the outer coils. Each of the filters for which data is shown in **fig. 4** was adjusted in this manner and then measured with no further *peaking*.

The coils may also be adjusted for resonance with-

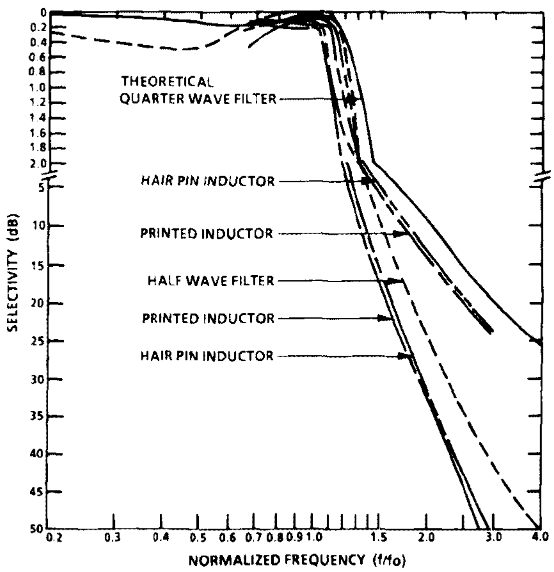
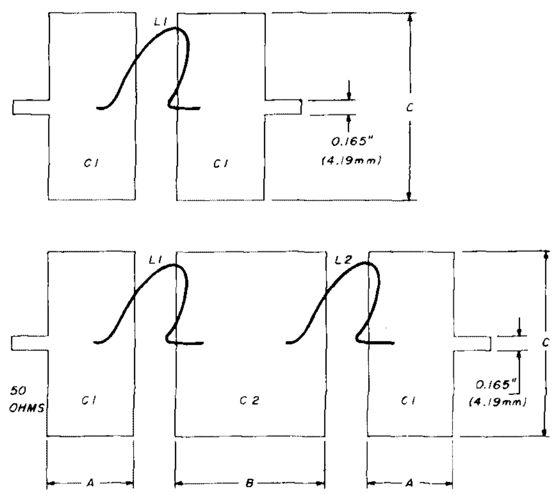


fig. 11. Experimental results for 450-MHz stripline quarter-wave and half-wave filters.



Design Frequency	Dimensions			Values				
	A	B	C	C1	C2	L1,2	Height	Width
450 MHz	0.334"	0.694"	2.0"	7.07 pF	14.1 pF	17.7 nH	1/2"	1/4"
1,300 MHz	0.228"	0.472"	1.0"	2.5 pF	4.9 pF	6.1 nH	1/4"	1/8"

Table 2. Hairpin inductor multiple-quarter-wave filter dimensions.

out the short circuit. The inductor in the quarter-wave circuit of **fig. 12A** will resonate with the series combination of the end capacitors. The value of capacitance will then be one-half the value of either capacitor, with a resonant frequency of

$$f_{resonant} = \sqrt{2}\ fo = 1.414\ fo \qquad (12)$$

The resonant frequency is 76 MHz, for example, for a 6-meter low-pass filter designed for an upper cutoff frequency of 54 MHz. The half-wave circuit shown in **fig. 12B** may be adjusted without using a short in a similar manner if only one inductor is connected at a time. The resonant frequency formed by 2C, L, C is

$$f_{resonant} = \sqrt{3/2}\ fo = 1.225\ fo \qquad (13)$$

which is 66 MHz for an upper cutoff frequency of 54 MHz. If both inductors are present, the circuit will resonate at $\sqrt{2}\ fo$. *The resonant circuit will be com*posed of a capacitor of 2C in parallel with two series circuits of L and C.

Hairpin inductors are adjusted for minimum loss using the transmitter and a power meter. As the hairpin is adjusted closer to the ground plane, the resonant frequency is decreased. The inductance is

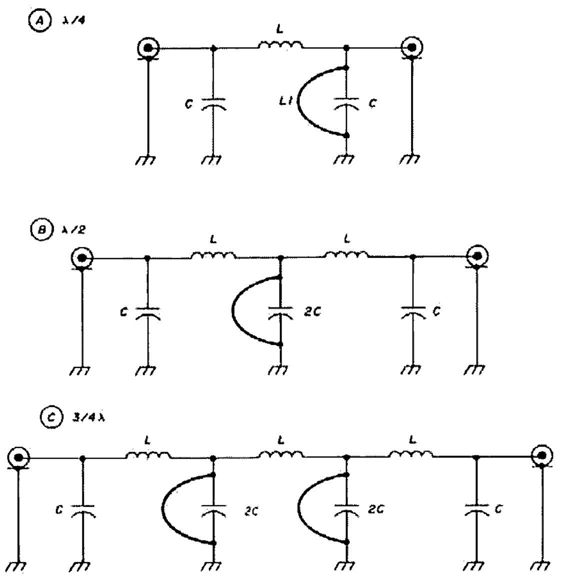


fig. 12. (A) The quarter-wave filter is adjusted by forming a parallel resonant circuit. (B) The half-wave filter is adjusted by resonating each end section. (C) The three-quarter wave filter center inductor is adjusted to resemble the end sections.

decreased, but the shunt capacity increases by a greater amount. The insertion loss of the multiple quarter-wave filter increases if low quality components are used. Coils typically have a lower inherent Q than capacitors. The dissipative insertion loss for a quarter-wave filter is given by

$$Dissipative\ Loss\ (dB) = 10 \log \left[1 - (Q_T / Q_{COIL})\right] \qquad (14)$$

The loss for a half-wave filter is simply twice the loss of a quarter-wave filter.

references

1. Doug DeMaw, W1FB, "Transmitter Design — Emphasis on Anatomy," *QST*, July, 1978, pages 23-25.
2. Bill Orr, W6SAI, "Ham Radio Techniques," *ham radio*, February, 1982, pages 60-62.
3. Bill Orr, W6SAI, *Radio Handbook*, Twentieth Edition, Editors and Engineers, Indianapolis, Indiana, 1978, pages 16.8-16.9.
4. Elmer A. Wingfield, W5FD, "New and Improved Formulas for the Design of Pi and Pi-L Networks," *QST*, August, 1983, pages 23-29.
5. Standex Electonics, 4538 Camberwell Road, Cincinnati, Ohio 45209.
6. SEMCO, Route 6 North Windham Road, Willimantic, Connecticut 06226.
7. Donald Kochen, K3SVC, "Practical VHF and UHF Coil-Winding Data," *ham radio*, April, 1971, pages 6-14.
8. Leonard H. Anderson, "Self-Supporting Coils," *ham radio*, July, 1977, pages 42-45.
9. Ernie Franke, WA2EWT, "The Hybrid Ring," *ham radio*, August, 1983, pages 50-58.

ham radio

PRACTICALLY SPEAKING ... Joe Carr KA1PV

revisiting the "poor man's spectrum analyzer": digitally generating sawtooth (and other) waveforms

In the March, 1987 column we discussed the "Poor Man's Spectrum Analyzer," which I built from an article published by W4UCH.[1] The design was originally put together by Murray Barlowe, WA2PZO, of Science Workshop.[2] In that column I mentioned that the sawtooth generated for that project left something to be desired, and offered a digitally generated improved sawtooth generator design to anyone who sent me a No. 10 SASE. Nearly 30 people wrote to me either via *ham radio*, my old callbook QTH, or my new QTH (see end of this article). As a result, I've decided to publish that circuit here. The response to my offer delighted me because it indicates that the doomsayers are wrong: Amateur construction is not dead!

Figure 1 shows part of the problem with the original sawtooth generator circuit. In my previous column on this subject, I showed several different sawtooth waveforms that were worse than **fig. 1**; this version is the *best* case. The waveform has two defects which adversely affect the operation of the spectrum analyzer. First, the rising ramp part of the sawtooth isn't linear. Because the original design was a capacitor charge/discharge circuit in the form of a Miller integrator, the ramp naturally has a shape like the normal capacitor charge waveform. What's required of a proper sawtooth is a linear ramp. The second defect is the fall-time: it's too long. Use of a few low-cost digital components produces a better sawtooth waveform.

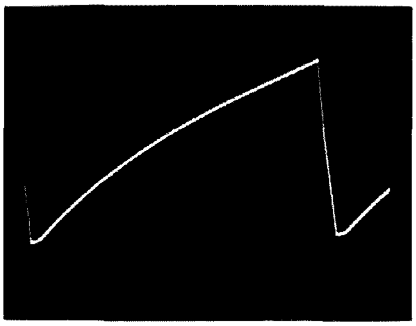


fig. 1 Best waveform available from the sawtooth generator.

The circuit for the new sawtooth generator is shown in **fig. 2**. The heart of this circuit is U1, a DAC0806 eight-bit digital-to-analog converter (DAC). This DAC, based on the Motorola MC-1408 family of DACs, was selected because it's well behaved and available through mail order sources such as Jameco Electronics[3] or in blister packs through Jameco's local distributor line of *Jim-Paks*.

A DAC produces an output voltage that is proportional to the reference voltage or current and the binary word applied to its digital inputs. The transfer function of this DAC is:

$$I_o = I_{REF} \cdot \frac{A}{256} \qquad (1)$$

where:

I_O is the output current from pin 4;

I_{REF} is the reference current applied to pin 14, and

A is the decimal value of the binary word applied to the eight binary inputs (pins 5-12).

The reference current is the reference voltage divided by the series resistor value at pin 14. In data systems the reference voltage is a precision, regulated potential. But in this case we don't need that precision, so we can use the V+ power supply as the reference voltage. Therefore, the reference current is (+12 Vdc)/R4. With the value of R4 shown (6800 ohms), I_{REF} is 0.0018 amperes, or 1.8 mA. Values from 500 μA are permissible with this device. If you elect to change the reference current, be sure to keep R4 equal to R5.

The reference current sets the maximum value of output current, I_O. When a full-scale binary word (11111111) is applied to the binary inputs, the output current I_O is:

$$I_o = (1.8\ \mu A) \cdot \frac{255}{256} = (1.8\ \mu A) \qquad (2)$$

$$\cdot\ (0.996) = 1.78\ \mu A$$

the DAC0806 is a current output DAC, so we must use an op amp current-to-voltage converter in order to make a sawtooth voltage function. A circuit that accomplishes this is an ordinary

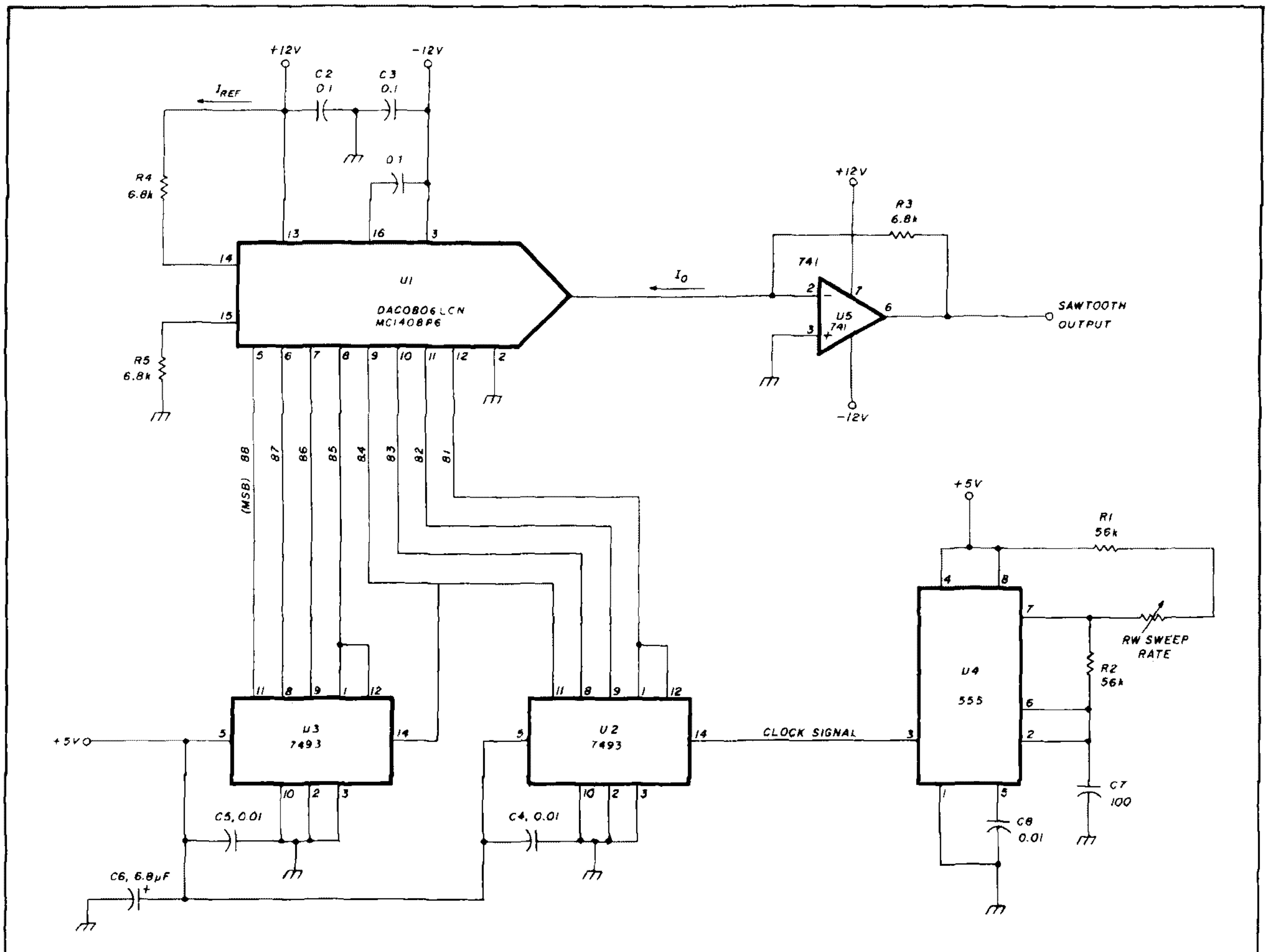


fig. 2. Digital sawtooth generator circuit.

inverting follower without an input resistor. The output voltage (V_O) will rise to a value of ($I_O \times$ R3).

The waveform produced by this circuit is shown in **fig. 3**. This waveform has a period, T, of about 5 ms (1/T = 200 Hz), and an amplitude of about 5 volts. In **fig. 3A**, notice that the falling edge is too fast for the oscilloscope camera to photograph (contrast this with the **fig. 1** waveform). The leading edge of this latter waveform also represents an improvement. An expanded view of the positive-going ramp is shown in **fig. 3B**.

The actual output waveform is a staircase of binary steps, each equal to the 1-LSB (Least Significant Bit) current of U1 (or the 1-LSB voltage of V_O). The 1-LSB voltage is the smallest step change in output potential caused by changing the least significant bit (B1) either from 0 to 1, or from 1 to 0. You don't see it in **fig. 3** because the frequency response of the 741 operational amplifier used for the current-to-voltage converter acts as a low-pass filter to smooth the waveform. If a higher frequency op amp is used, then a capacitor shunting R3 will serve to (low-pass) filter the waveform. Although I haven't tried other op amps in this application, I suspect a -3 dB frequency (f) of 1 or 2 kHz will suffice to smooth the waveform. The value of the capacitor is calculated from:

$$C = \frac{10^6}{6.28\ R3 \cdot f} \qquad (3)$$

where:

C is the capacitance in microfarads;

f is the −3-dB cutoff frequency in Hz;

R3 is expressed in ohms.

This circuit is synchronized by a clock oscillator consisting of a single 555 IC timer. Although not a TTL device, the 555 is TTL-compatible when the V+ potential applied to pins 4 and 8 is limited to +5 Vdc. The 555 is connected in the astable multivibrator configuration and generates a +4 volt amplitude series of pulses. The operating frequency is set by three resistors (R1, R2, and RW) and capacitor C7. The actual frequency is:

$$f = \frac{1.44}{((R1 + RW) + 2R2)\ C7} \qquad (4)$$

where:

f is the frequency in Hz;

C7 is in farads;

R1, R2 and *RW* are in ohms.

Select a clock frequency that is 256 times the desired sawtooth sweep frequency. For most spectrum analyzer projects the sweep frequency range will be 10 to 200 Hz. Slower rates make viewing on the CRT screen difficult, while faster rates may tend to "ring" the bandpass filter used in the i-f amplifier section.

waveform selection

As electronic music buffs will testify, we can get almost any waveform we need by applying the right binary words to the digital inputs of the DAC0806. Because I wanted a sawtooth waveform, the DAC inputs were connected to the outputs of an eight-bit binary counter built from a pair of 7493 TTL base-16 counter chips. Each chip is a four-bit counter, so they are cascaded to produce the eight-bit binary word needed to drive the DAC. If you want a detailed description of this chip, I recommend Don Lancaster's book *TTL Cookbook*.[4] The function of this counter is to increment in steps from 00000000 to 11111111 under control of a clock signal applied to the input (pin 14) of U2. You could use any eight-bit counter that outputs a TTL-compatible signal in place of the 7493 devices that I selected. The 7493 was chosen for the best of all engineering reasons: I had a pair of them in my junkbox.

If you want a triangular waveform, then it's possible to replace the 7493 devices with a base-16 up/down counter chip. Arrange the digital control logic to reverse the direction of the count when the maximum state (11111111) is sensed.

There are two ways to generate waveforms other than a sawtooth or triangle, and both of them involve using computer memory. The binary bit pattern representing the waveform, and then output in the right sequence, are stored in memory. One method uses a ROM that you pre-program with the bit pattern. A binary counter circuit connected as an address generator selects the bit pattern sequence. The second method stores the bit pattern in a computer, then outputs it under program control via an eight-bit parallel output port. This method is usable for both generating special waveforms and for linearizing the tuning characteristic of the spectrum analyzer.

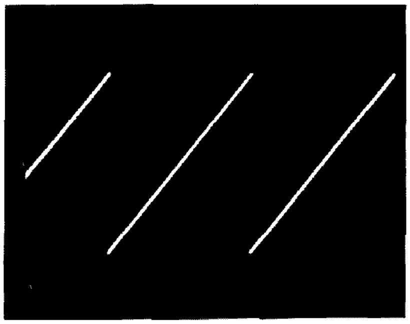


fig. 3A. Waveform from the digital sawtooth generator: three successive waves.

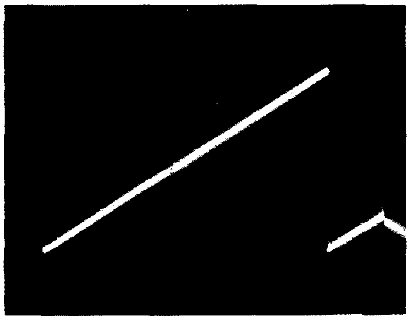


fig. 3B. Waveform from the digital sawtooth generator, expanded to show greater detail.

The varactor TV tuner that forms the basis of this project has a nonlinear voltage vs. frequency characteristic. This is due to both the nature of varactor diode voltage vs. capacitance curves, and to the fact that the change of frequency in an LC tank circuit is proportional to the square root of the change in capacitance. For this reason I suspect that the actual mathematical function of the curve is basically parabolic (i.e., it looks as if it might approximate a quadratic "$aX^2 + bX + c$" function).

There are a couple of methods that can be used for the linearization process. First, the analog method involves the use of an XY/Z analog multiplier divider circuit (a special IC). These devices can be connected as a "square rooter" stage. There are two problems with this: first, that the values of the constants must be determined (which is not so easy) and second, that many of these ICs tend to be either expensive or temperamental, especially to changes in temperature. However, there is a digital solution.

The digital solution to the linearization problem involves storing a lookup table in either a ROM or computer memory. I learned this system in a medical electronics laboratory where it was once used to linearize low-level pressure transducer measurements. **Figure 4** shows a generic version for a voltage that represents some parameter P, which in our case might be the frequency of the spectrum analyzer local oscillator. The actual nonlinear curve could be any shape, including parabolic, while the "ideal" curve is a linear function $Y = mX + b$, where $b = 0$. The idea is to measure the ideal voltage (which in our case is generated by the sawtooth or tuning control) with an A/D converter, and then output a binary word to a DAC that represents the actual required voltage. For example, at point P1 the ideal voltage is 0.9 Vdc, while the actual voltage is 0.68 Vdc. When the computer senses an ideal voltage of 0.9, it creates an actual voltage of 0.68 in order to drive the tuning to the correct frequency.

Another concept is to go all digital, except for the DAC that creates the actual tuning voltage. We could, for example, divide the spectrum up into N segments and store the binary codes for the correct tuning voltages in memory for each discrete point. The value of N corresponds to the bit length of the DAC. **Figure 5** shows a simplified block diagram of such a system. Tuning is controlled by a clock that drives the binary counter. The N-bit binary word output from the counter is routed to the address pins on the ROM. Contained in the ROM is the bit pattern for each of the 2^N discrete vol-

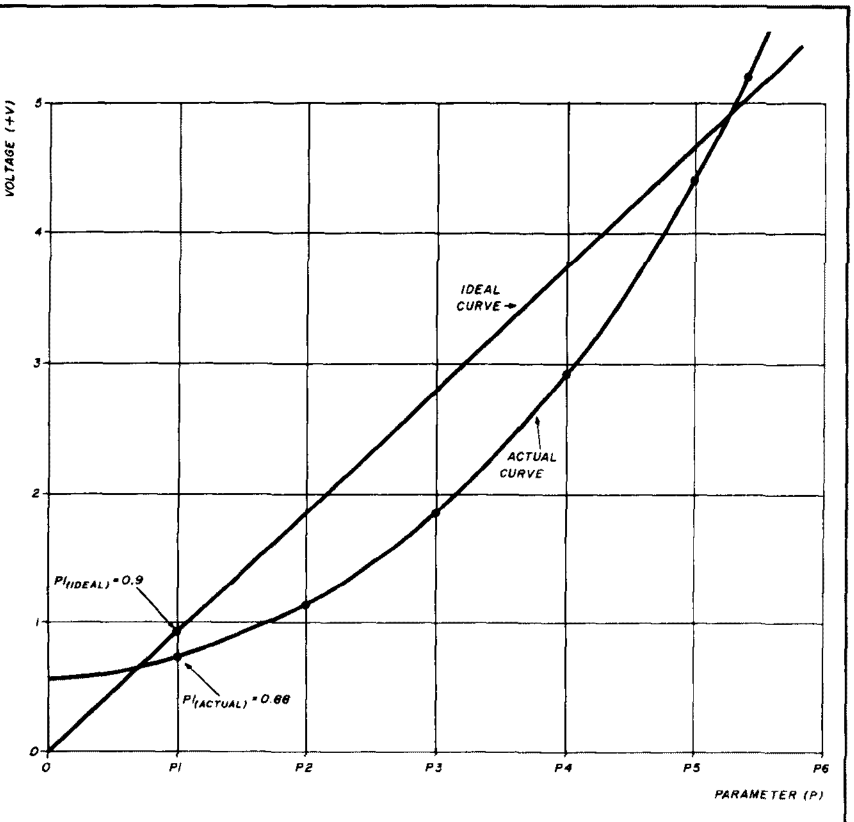


fig. 4. Example of linearization process.

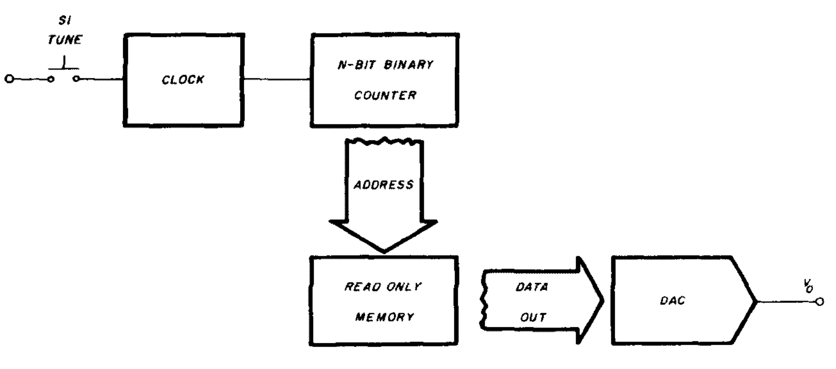


fig. 5. Suggested starting point for an all-digital linearizer.

tages that can be generated by the system. The correct binary word corresponding to this calibrated discrete potential is routed to the DAC, which generates the correct voltage. I haven't developed this circuit, but suspect that it wouldn't be too difficult once an accurate and correct voltage vs. frequency chart is known for any given tuner (that curve is the source of the data that is contained in the ROM).

a note from WA2PZO

After my initial column on this topic appeared, WA2PZO sent me a note on the feedthrough capacitors used in the project. (I had complained about the high cost, but have since learned that Dick Smith Electronics[5] stocks them for less than 50 cents each.) Murray informs me that he no longer advises bypassing *all* of the leads because the capacitance tends to integrate the waveform, makes the receiver less usable as a monitor receiver, and introduces a little instability. If you installed bypass capacitors on the leads into the shielded i-f box, remove all of them except the one on the + 12 Vdc regulated power supply line.

One reader wrote about an "inverted scope image" problem, which I am at a loss to describe. If anyone has had this problem and solved it, then please pass the solution on to me and I'll pass it on to the affected reader. If it's of sufficient interest, perhaps we'll find space to cover it in a future issue.

WA2PZO now has a tracking generator kit available for the "Poor Man's Spectrum Analyzer." It consists of a modified tuner and some extra parts that go on the SW-6006 i-f board. Write to him for details. In the meantime, I'm planning to build it and evaluate it in this space sometime in the future. I don't want to devote much space to this project because of all the other pressing issues that interest readers . . . but a tracking generator has definite possibilities!

references

1. Science Workshop, Box 393, Bethpage, New York 11714.
2. Robert M. Richardson, W4UCH, "Low-Cost Spectrum Analyzer with Kilobuck Features," *ham radio*, September, 1986, pages 82-90.
3. Jameco Electronics, 1355 Shoreway Road, Belmont, California 94002. (Catalog available for $1.00 postage and handling.)
4. Donald Lancaster, *TTL Cookbook*, Howard W. Sams & Co., Inc. Available from Ham Radio's Bookstore, Greenville, New Hampshire 03048; $14.95 plus $3.50 shipping and handling.
5. Dick Smith Electronics, P.O. Box 2249, Redwood City, California 94064. (148-page catalog available for $1.00 postage and handling.)

Joe Carr, K4IPV, can be reached by mail at P.O. Box 1099, Falls Church, Virginia 22041.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

happy days are here again?

Something happened last spring. After many months of mediocre conditions, the DX bands came alive. Twenty meters was open until almost midnight, alive with mouth-watering signals. Long-distance DX contacts, heretofore a weak, watery S1 to S2, were now booming in S9-plus. I amazed myself by working a UA1 on 15 meters, something that hadn't happened for many years. DX signals were even coming through on 10 meters!

Although this activity decreased somewhat with the summer lull and high static level, it seems to be picking up with increased vigor this fall. For Amateurs licensed within the last five years, radio conditions over the next several years — as the sunspot cycle increases rapidly — are going to hold big surprises. . . you ain't seen nothin' yet!

the two-band loop antenna

It's not easy to get an effective DX antenna that will work on both 80 and 40 meters. By "80 meters," I mean both CW operation at the low end of the band and SSB operation near the DX slot at 3.8 MHz. It looks as if Jack McCullough, W6CHE, has found an answer — providing you have a modest tower and a small amount of real estate. Jack's solution to the 80/40-meter dilemma is shown in **fig.**

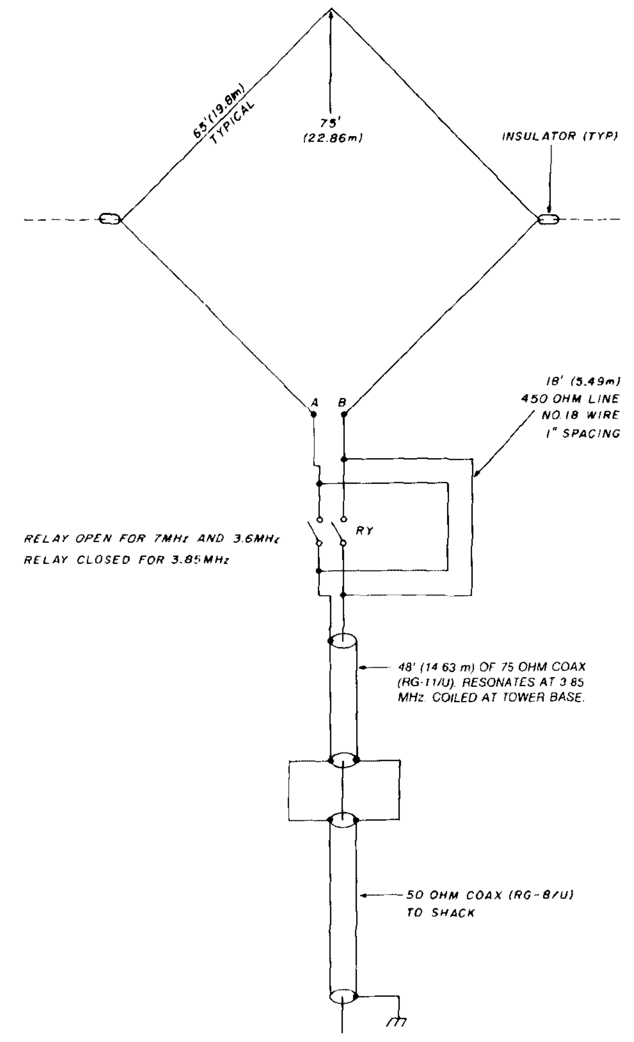


fig. 1. W6CHE 40- to 80-meter quad loop.

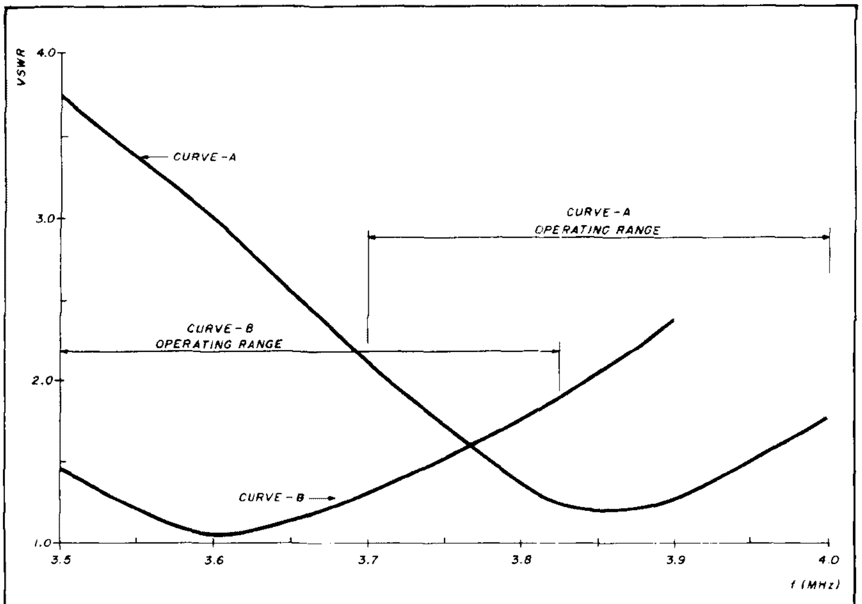


fig. 2. Operating range of W6CHE loop with relay (A) closed or (B) open.

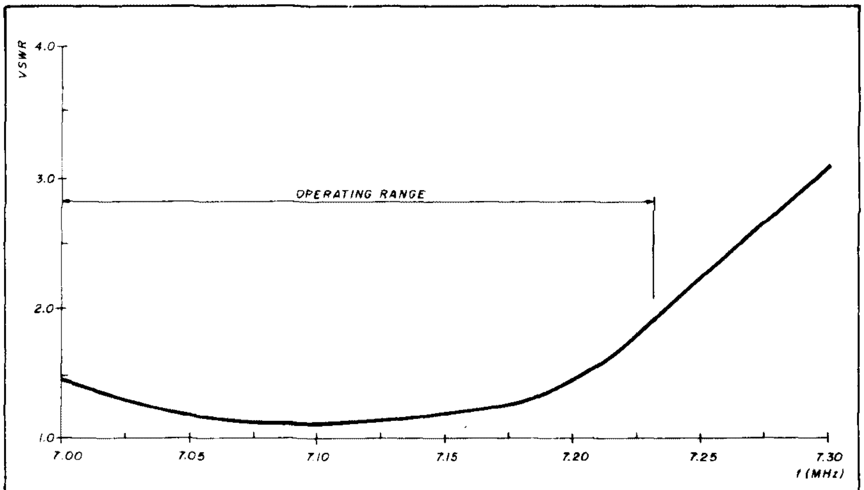


fig. 3. Operation of W6CHE loop at end of 40-meter band (relay open).

1. The basic antenna is a single 80-meter diamond-shaped Quad loop measuring 65 feet on a side and hung from the top of a 75-foot tower. Since the overall height of the diamond from base to apex is about 90 feet, the loop plane is tilted out at the base, away from the tower. The assembly, thus, is not in the vertical plane. If you have a higher tower, the loop can be mounted in the vertical plane.

The loop is fed with a 50-ohm coax line, plus a 48-foot section of RG-11/U (75 ohm) coax which serves as a matching transformer. The line is cut to 3850 kHz with the aid of a dip meter.

80-meter operation

A double-pole relay is placed between the matching section and the feedpoints of the loop. When the relay is closed, the loop is resonant at 3.8 MHz. When the relay is open, the loop is lengthened by means of an 18-foot section of 450-ohm open-wire line. The loop is now resonant near 3.6 MHz (see **fig. 2**). Thus, by the flick of a switch, the antenna can be made resonant at either end of the 80-meter band, providing a low value of SWR to the transmitter.

40-meter operation

Operation across the lower portion of the 40-meter band is possible when the relay is either open or closed. The best situation is shown in **fig. 3**, with the relay in the open position. The operating range, as defined in the curves, is about 7.0 to 7.25 MHz.

The secret of moving the Quad loop about in frequency is the length of the matching stub. Obviously a different length stub is required for operation at the high end of the 40-meter band.

The final W6CHE loop design is shown in **fig. 4**. Two relays and two stubs are used. One stub is 15 feet long and the other is 4 feet long. In series connection, they represent a stub about 19 feet long. The stubs are switched in and out of the circuit by means of a two-pole, three-position rotary switch at the operating position. Power is applied to the relays by means of a separate switch which energizes the dc supply. Switching sequence for the various frequency ranges is listed in **table 1**.

a temporary wire antenna for 80, 40 and 20 meters

A friend of mine moved into a temporary location and wanted to get on the high frequency bands with an unobtrusive antenna. He and I thought about it for a while and finally decided on an end-fed wire working against a radial ground system (**fig. 5**). On 160 meters, the antenna is about 3/16 wavelength long; on 80 meters, about 3/8 wavelength; on 40 meters, about 3/4 wavelength; and on 20 meters, about 3/2 wavelengths. On all bands except 160 meters, the feedpoint impedance runs between 65 and 180 ohms. On 160 meters, it's about 10

Table 1. Switching sequences for W6CHE loop.

Frequency Range (kHz)	SW1	SW2	Total Stub Length
3500-3650	open	—	19 feet
3550-3750	closed	Position 1	15 feet
3700-3900	closed	Position 2	4 feet
3750-4000	closed	Position 3	—
7000-7125	open	—	19 feet
7125-7300	closed	Position 1	15 feet

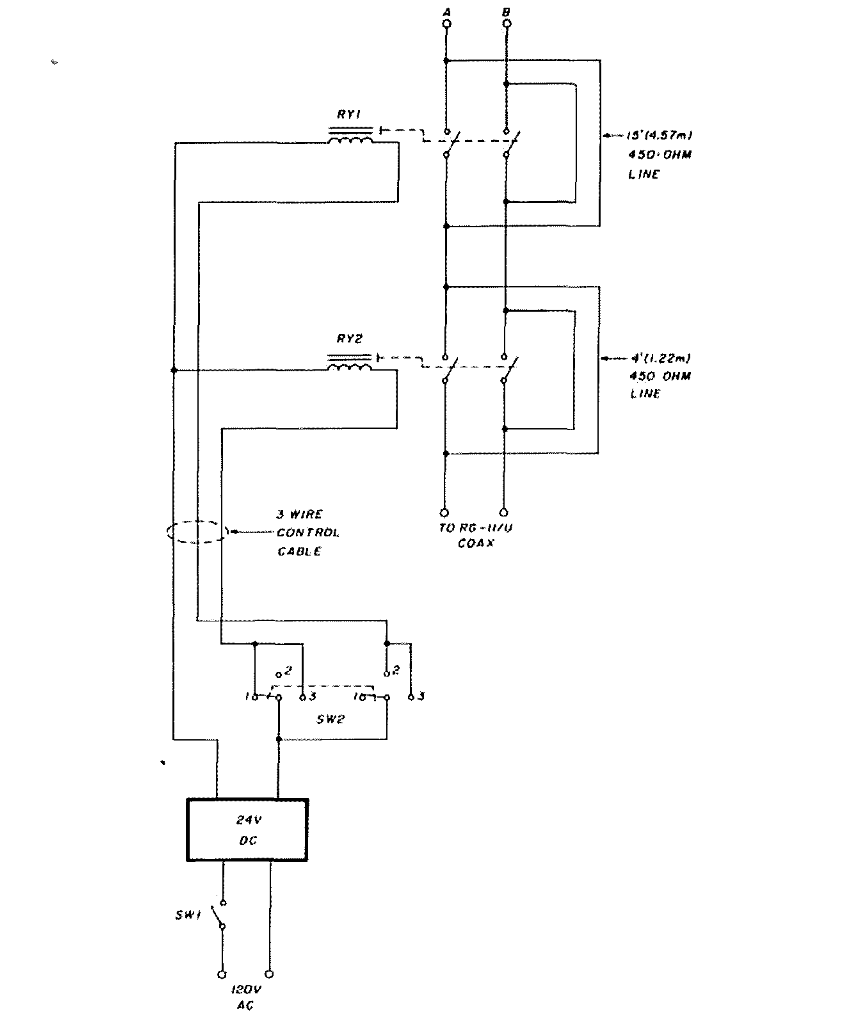


fig. 4. Dual-relay arrangement for operation on the different segments of the 40- and 80-meter bands (see table 1).

ohms. An L-network at the base is used to feed the antenna.

Successful operation depends upon a good radial ground termination at the base of the antenna. A combination of two ground rods, plus quarter-wave

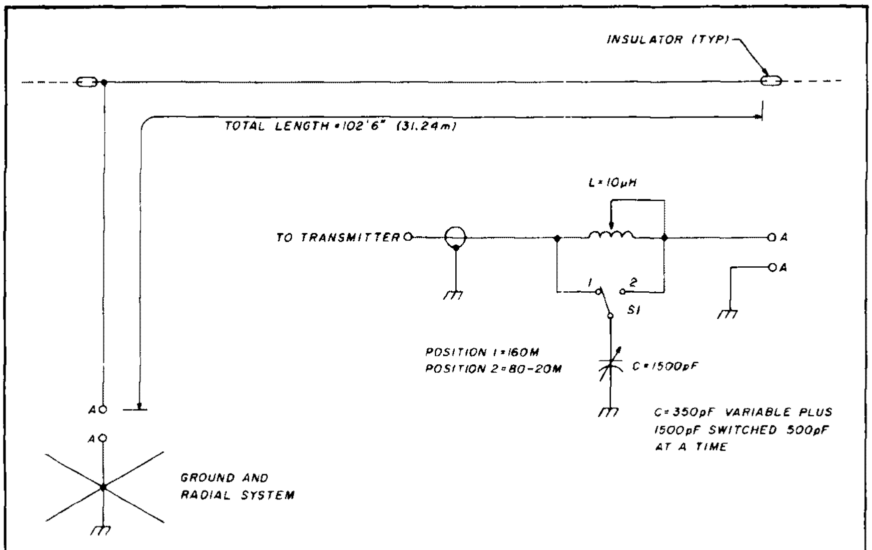


fig. 5. Multiband, end-fed wire antenna for 160 to 20 meters.

radials laid upon the surface of the ground will do the job. The more radials, the better.

In this particular installation, the vertical portion of the antenna is about 35 feet, or approximately a half-wavelength on 20 meters.

Since the antenna terminates just outside the radio room, the network is placed in a waterproof box that can be reached in seconds when a band change is desired.

The antenna was adjusted first on 80 meters. The terminals at A-A were shorted together with a one-turn loop and the antenna cut for resonance at 3.5 MHz, with the aid of a dip meter. The flat-top was pruned to achieve the proper electrical length. This makes the antenna slightly short for operation on 40 and 20 meters, but the L-network takes care of the situation. It also permits operation of the antenna at the high-frequency end of the 80-meter band with a low value of SWR at the transmitter. The L-network capacitor is reversed by S1 for 160-meter operation, and the frequency response without retuning on this band is only about 25 kHz.

While its performance on 20 meters isn't equal to that of a Yagi on a 60-foot tower, it does permit plenty of enjoyable QSOs in a location where a more robust and permanent antenna would be impossible to erect.

15-meter Yagi

I received a letter from "Mac" McDaniel, W4PFZ, that brought joy to my heart. Mac says:

Back in the February, 1955, issue of CQ, you described a two-element Yagi with data for making it a three-element array. I was living in Richmond, Virginia, at the time and made an exact copy of the beam. It had plenty of gain, and local hams were surprised at the front-to-back ratio, which seemed to be about 36 dB.

Over the course of many years I have moved frequently and the beam has been disassembled and reassembled several times. I now have the original beam up on a 55-foot wooden pole. Every time I check the front-to-back ratio on ground wave I come up with numbers between 32 and 38 dB.

I adhere to the philosophy of "if it ain't broke, don't fix it," and have never changed a single dimension since first building the beam in 1956. I've replaced the variable gamma capacitor several times and reset it for resonance at 21.3 MHz, which takes about 10 minutes.

The last time I reworked the gamma match, I did it with the beam near the ground, pointed up at the sky. It was easier than working atop the pole and the final result is no different than adjusting the match at the top of the pole.

I thought you might like to hear about the success obtained from following your construction information in an article written over 30 years ago!

Designed long before computer-aided programs were available, the beam Mac speaks about represents a configuration determined by field strength measurements made on a crude antenna range. The inner portions of the elements were made of 12-foot lengths of 1-inch diameter aluminum tubing and the tip sections were made of 7/8-inch diameter tubing. Elements were attached to the boom by means of 8 x 8-inch aluminum plates oriented diagonally so the actual contact with the boom and the elements was about 11 inches.

The ends of each center element were slotted with a hacksaw to a depth of about 1 inch and stainless steel hose clamps were tightened around the slots. A band of red paint was put around each outer section so it could be reassembled exactly as it was originally.

Since 15 meters is coming back to life, I'm reprinting my original Yagi design for those DXers who might want to build their own beam (**fig. 6.**).

The boom is a single section of heavy-wall tubing, 1 inch in diameter. Dimensions are given for resonance at 21.3 MHz.

The only adjustment required is that of the gamma matching device. Length and spacing of the gamma rod are set as illustrated and a small amount of power is fed to the beam via an SWR meter. The variable capacitor is adjusted for the lowest value of SWR. In some cases, it may be necessary to move the shorting strap between the driven element and the matching rod a few inches one way or the other to achieve a near-unity SWR figure.

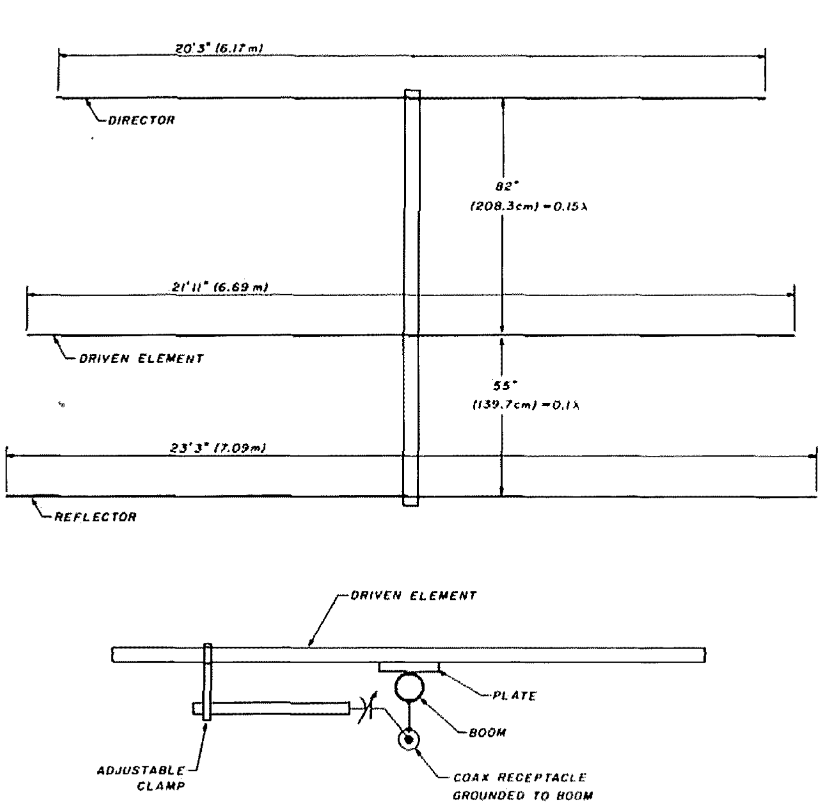


fig. 6. The W4PFZ version of the original W6SAI beam for 15 meters using 12-foot boom.

Although I've never done it, W4PFZ suggests that the beam can be adjusted on the ground by supporting it in a vertical position, with the director pointing up at the sky and the reflector clear of the ground by a few feet. This sounds a lot easier than hanging by your heels atop the tower to adjust the gamma capacitor!

In the original design, the gamma capacitor was mounted inside a 3 x 4 x 5-inch aluminum "minibox." It was isolated from the box by means of an insulating plate. The box was grounded to the antenna boom. A coax fitting for the feed line was placed on one end of the box and a ceramic feedthrough insulator at the other end of the box supported the gamma rod. The shaft of the capacitor could be adjusted through a hole in the box. After adjustment, the hole was closed with several layers of tape to prevent water from entering the box. The seams of the box were coated with roofing compound for the same reason.

Commercial 6061 or aircraft alloy 2024 tubing are recommended for construction of the elements. To retard oxidation at the element joints, a special lubricant, such as the grease employed in industrial power installations that use aluminum conduits, is used. (Some of the trade names for this compound are *Penetrox,*® *Cual-aid,*® and *Ox-guard*®. The compound is smeared lightly over the tubes before they are joined.

I don't know whether many Amateurs build their own beams from scratch today, or if they buy pre-cut kits from a manufacturer. I'll be interested to hear if anyone duplicates this proven antenna and what kind of results they achieve with it. Good luck!

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

minimum requirements for 2-meter EME: part 2

Last month's column was an introduction to 2-meter EME communications, including explanations of EME terminology.[1] With that information in place, we can concentrate on the minimum requirements, recommended equipment, and operating techniques.

the minimum station

As I stressed in earlier articles,[1,2,3] the goal should be to build a station that allows you to hear your own echoes if all conditions are favorable; I call this the "minimum station" (**fig. 1**). This setup includes the "built-in test" feature described in reference 1 so you'll be able to verify that your gear is functioning properly. You'll not only be able to have successful EME contacts — you'll be able to quickly evaluate system changes and improvements as well.

Table 1 shows the typical minimum parameters and equipment necessary. As you can see, the path loss is staggering compared with path loss on hf, where signals are typically attenuated only 75 to 175 dB. This is part of what makes EME communications such a challenging sport!

It may be worthwhile for those who are mathematically inclined to see how EME path loss is calculated. Sometimes the so-called "radar equation" is used[4]:

eqn 1:

$$R_{max} = [(P_t\ G\ A_e\delta)\ /\ ((4\pi)^2\ S_{min})]^{1/4}$$

where R_{max} is the range in kilometers, P_t is the transmitter power in watts, G is transmitter antenna gain in dBi, A_e is the effective aperture of the antenna in meters squared, δ is the radar cross section of the target in meters squared, and S_{min} is the minimum detectable signal in watts.

Because **eqn. 1** isn't easily adaptable for Amateurs on EME, I prepared **eqn. 2**, which is oversimplified and not applicable to the higher bands, where the sky noise is very low. This simplified "2-meter EME radar equation" is useful for evaluating the elements of a station that uses the same antenna for transmitting and receiving. The reference is the received signal level at the antenna feedpoint based on a 50-ohm impedance:

$$P_r = P_t + 2(G_a) - P_l \qquad \textbf{eqn. 2}$$

Where P_r is the received signal power in dBm (level with respect to 1 milliwatt), P_t is the transmitted power in dBm measured at the antenna feedpoint, G_a is the antenna gain in dBi referenced to the feedpoint, and P_l is the path loss in dB.

For example, let's evaluate the minimum station shown in **table 1**. P_t is the transmitted power at the antenna feedpoint, 500 watts or +57 dBm. G_a is the antenna gain, +20 dBi. P_l is the nominal path loss, or 252.5 dB. Therefore, the received power level at the feedpoint is approximately −155.5 dBm (0.0038 microvolts), a very weak signal! (More on this shortly.)

Antenna gain deserves some further comment. As mentioned before, when calculating EME performance, antenna gains are usually specified in dBi (dB over isotropic), since the path loss is specified in the same terms. Just add 2.15 dB to any antenna gain specified in dBd (gain over a dipole) and you'll be all set. If you use stacked antennas, you'll have to estimate the overall system gain (see references 5 through 7). When estimating antenna system gain, don't forget to subtract the phasing line loss.

As discussed in last month's column, it is common EME practice to use the same antenna on both transmit and receive. The most important EME parameter in **eqn. 2** is antenna gain; every time the EME antenna gain increases by 1 dB, the total system performance improves by 2 dB (1 dB stronger on transmit and 1 dB on receive). Therefore, **eqn. 2** clearly shows that you should spend most of your EME efforts on perfecting your antenna system.

The transmitted power is well understood. Any increase here is on a dB-for-dB basis. Generally, increasing transmitted power helps the other station hear you better. If you have a 1-dB feed line loss between the output of your final power amplifier and the antenna system, a typical setup on 2 meters, 625 watts is required in the shack so that the required 500 watts will be present at the antenna. Therefore, increasing the transmitter output to the new FCC limit of 1500 watts will increase your signal by only about 3.8 dB, at a considerable expenditure in power amplifier cost.

Finally, there are the receiver considerations. The one most often discussed parameter is the noise figure. Usually, the lower the noise figure, the more sensitive the receiver, and the better you can hear the weak signals returning from the moon. However, on

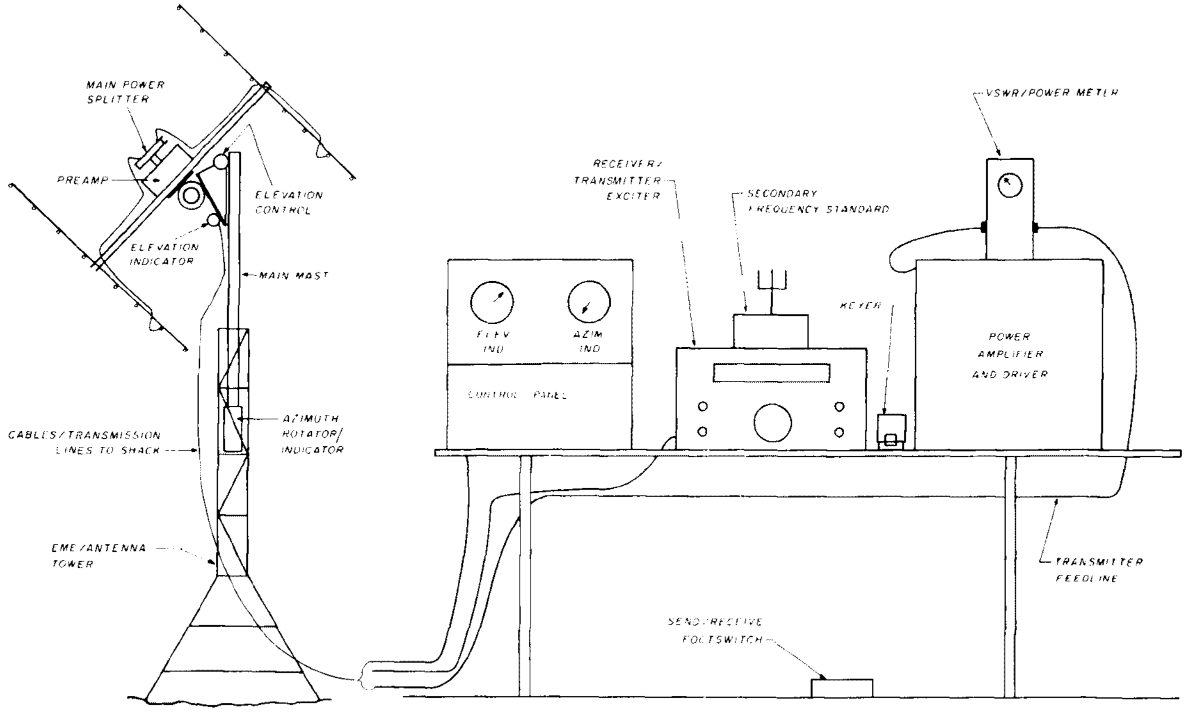


fig. 1. This figure shows the primary elements of a "minimum" 2-meter EME station as described in the text.

Table 1. This table shows the minimum requirements for successful 2-meter EME echoes as discussed in the text.

Path loss	252.5 ± 1 dB
Minimum antenna gain	20 dBi
Minimum transmitted power at antenna feed	500 watts (+57 dBm)
Maximum receiver noise figure referenced to the antenna feedpoint	1.5 dB
Receiver bandwidth	50 Hz

2-meter EME the law of diminishing returns applies. You're limited not only by the feed line loss in the antenna system, but by the noise the antenna "sees" as well (see reference 1). If your antenna feed line loss ahead of your preamplifier is low (i.e., 0.5 dB maximum), you probably won't gain much improvement by using a noise figure below 1.0 dB. This will be discussed below.

a marginal 2-meter EME station

By now you're probably wondering, "But what if I don't want to go all the way and build a minimum EME station? What are the *minimum* requirements?" All other parameters being equal, the only requirement that has to be satisfied is that the sum of the antenna gains at both stations be equal to or greater than 40 dBi. Therefore, if the other station has a 25-dBi antenna gain, you can have successful QSOs with only a 15-dBi antenna gain — the gain of a single high-performance Yagi on a boom measuring three wavelengths or longer.

If you have the minimum 20-dBi antenna gain and schedule a station sporting 25 dBi of gain, you can use power levels down to 5 dB lower, or as low as 150 watts at the antenna feedpoint! This explains why the "super stations" have *been so* successful; they have much greater gain than is required for the minimum station and usually have very low feed line losses, with very low-noise receivers with the preamplifier mounted at the antenna feedpoint. Running the maximum legal power of 1500 watts, they've obviously overcome the inadequacies of smaller stations.

Other EME tradeoffs are possible. Sometimes conditions are particularly favorable, especially if Faraday rotation cooperates, some scintillation enhancement is present, the moon is near perigee, and the sky temperature is low. Furthermore, as mentioned in last month's column, "ground gain," though elusive, can sometimes result in several dB of enhancement. This is particularly important to stations that don't have antenna elevation control

(such as in a tropo setup) but want to try EME. Most of the super stations will be glad to accommodate any schedule requests.

EME antennas and antenna systems

Since the antenna system is the main key to EME success, it should be discussed first. Many antenna types — rhombics, collinears, parabolic dishes, and Yagi arrays — have been used successfully on 2-meter EME.

W3GKP and W4AO used rhombic antennas in the early 1950s to hear the first successful Amateur EME echoes, which were on 144 MHz.[1] Stacked rhombics were later used by VK3ATN and then by VK5MC. For the type of gains required, rhombics must be very large, typically 40 to 50 wavelengths, or 275-350 feet on a side! A rhombic antenna is therefore practical only in a fixed configuration for horizon shots in a narrow EME window. Rhombics also have many sidelobes, so they can't be considered low-noise receiving antennas.

Collinears, both standard and extended, were among the first really successful rotatable 2-meter EME antennas. They're not difficult to build or tune and usually have open wire phasing lines so losses are low and efficiency is high. Though collinears are large, some Amateurs were able to arrange them so they could be rotated not only in azimuth and elevation, but also in polarity; this option often makes the difference between success and failure.

Parabolic dishes such as the 1000-foot diameter reflector at Arecibo, Puerto Rico, and the 150-footer at Stanford, California, were used several times for 2-meter EME in the 1960s. However, parabolic dish type antennas aren't too efficient (typically only 50 to 55 percent), and really have to be at least 28 feet in diameter to be worthwhile for 2-meter EME. Despite their shortcomings, dish type antennas require only a simple feed system, they're usually low-noise on receive, loss to the receive preamplifier can be negligible, and they can be easily adapted to polarity rotation. Moreover, they can usually be operated on higher frequency bands if the the feed system is changed.

Table 2. This table shows some of the most common individual antennas presently used on 2-meter EME along with boomlength, number of elements, and estimated gain. The gains shown represent my best judgment and are based on tests and reported results at 144 MHz; they may vary ±0.25 dB.

name and/or manufacturer	boomlength in wavelengths	no. elements	gain dBd	gain dBi
W1JR short Yagi [9]	1.73	8	11.35	13.5
NBS Yagi	2.2	12	11.85	14.0
Cushcraft 214B Jr. Boomer Yagi	2.2	14	12.1	14.25
Cushcraft DX-120 collinear	na	20	12.5	14.65
Tonna (F9FT) 20116 Yagi	3.15	16	12.5	14.65
KLM 13LBA Yagi	3.2	13	12.5	14.65
CueDee Yagi	3.1	15	12.85	15.0
NBS Yagi	3.2	17	13.05	15.2
Tonna (F9FT) 20117 Yagi	3.15	17	13.15	15.3
Cushcraft 3219 Boomer Yagi	3.2	19	13.2	15.35
NBS Yagi	4.2	15	13.55	15.7
KLM 16LBX Yagi	4.1	16	14.15	16.30
Cushcraft 4218XL Yagi	4.2	18	14.3	16.45
KLM 17LBX Yagi	4.7	17	14.5	16.65
M² Enterprizes (K6MYC) 2M-5WL	4.8	18	14.5	16.65
28-foot dish	na	na	17.55	19.7
32-foot dish	na	na	18.65	20.8
40-foot dish	na	na	20.55	22.7

Nowadays, the Yagi is "king" on 2-meter EME. Over the last ten years Amateurs have expended a great deal of effort towards improving Yagi gain and decreasing sidelobe levels. The result is vastly improved arrays with as many as 32 separate Yagis — with no end in sight! Furthermore, Yagis pack a lot of gain based on volume and form factor. No wonder back yard EME is now so popular.

Table 2, which shows the gain of some of the most popular individual 2-meter EME antenna designs, can be used as a guide to antenna selection. It's interesting to note that the majority of the popular commercial Yagis presently in use on 2-meter EME are based on either the NBS or DL6WU Yagi designs. The gains shown on this table have been either measured or calculated using some of the latest computer modeling techniques and represent true gain.

Because long Yagi designs may be expensive to build — given the high cost of materials — many antennas used on 2-meter EME are commercial types. Homebrewed Yagis are still very popular, however, despite the cost. Both the NBS and DL6WU designs are highly recommended; reference 8 discusses the advantages and disadvantages of these and other Yagi designs.

If you want to start small, consider the simple eight-element Yagi design on a 12-foot boom described in reference 9. Four of these antennas stacked only 9 feet horizontally and 8 feet vertically will make an excellent compact, low-cost, back yard starter EME antenna just shy of the minimum gain in **table 1**. The array can later be expanded to six or eight of these Yagis if greater gain is desired.

stacking antennas

Because no practical 20-dBi gain Yagi designs are presently available for 2-meter EME (11 wavelengths, 70- to 80-foot boomlength!), one usually has to resort to stacking smaller antennas. **Table 3** shows the maximum gain possible if Yagi antennas are stacked, based on zero phasing line losses. Note that system gain doesn't increase 3 dB every time you double the number of antennas, even with zero phasing line loss! To do so would incur large sidelobes, which would severely increase the noise temperature of the antenna, making reception very diffi-

Table 3. This table shows the typical stacking gain improvements for optimally stacked Yagi antennas, excluding any phasing line losses.

configuration	gain increase
2 antennas	2.75
4 Yagis	5.5
6 Yagis	7.1
8 Yagis	8.25
12 Yagis	9.85
16 Yagis	11.0
24 Yagis	12.6
32 Yagis	13.75

cult — especially on weak signals. Phasing line losses will decrease antenna performance accordingly. This is a big consideration when using four or more antennas.

Note in particular the stacking of six Yagis with only a two-times increase in size over four antennas for about 1.6-dB gain increase. This configuration is particularly recommended for Amateurs who just can't swing eight Yagis but need a little more antenna gain to stengthen their competitive edge.

The six-Yagi configuration is best accomplished by stacking them three high and two wide.[7] In the late 1970s, I built the power dividers and phasing lines for such a configuration and sent all the parts and information along with two extra antennas to Alaskan 2-meter EME station WA0LPK. Jim immediately installed the "kit" and went from 10-percent success on schedules to making contacts at random without schedules. While slightly more complex mechanically, this configuration has much to offer over going all the way to eight antennas with a three-times increase in size.

Table 4 shows examples of the gain of some of the more popular 2-meter EME Yagi antennas in typical stacking configurations. **Table 5** shows the estimated gain of some of the super stations. Many other configurations are available, but this should help.

Stacking antennas and using power splitter/combiners are discussed in detail in references 6 and 7, so that information won't be repeated here. First determine the gain of your single Yagi antenna; then you can estimate the gain improvement when they're stacked according to the information contained in **tables 3** through **5**.

Table 6 will help you determine the optimum spacing when stacking the antennas shown. Those not shown can be stacked using references 6 and 7 if the individual Yagi beamwidths and sidelobes are known. Don't get too worried about spacing — it isn't that critical, but if you must err, do so on the short side. Even a 10-percent shortening will decrease gain by only 0.25 dB and greatly decrease mechanical problems!

Table 4. This table shows some typical 2-meter EME arrays with estimated gains.

antenna and/or manufacturer	gain in dBd	gain in dBi
4 W1JR 8-el Yagis	16.85	19.0
4 Cushcraft 214B Jr. Boomers	17.60	19.75
4 16-el F9FT 20116 or KLM 13 LBA Yagis	18.00	20.15
80-el Cushcraft collinear	18.00	20.15
4 Cushcraft 3219 Yagis	18.70	20.85
4 KLM 16LBX Yagis	19.65	21.80
160-el Cushcraft collinear	20.75	22.90
6 KLM 16LBX Yagis	21.25	23.40
8 Cushcraft 3219 Yagis	21.45	23.60
8 KLM 16LBX Yagis	22.40	24.55

Table 5. This table shows the estimated antenna gain of some of the 2-meter EME "super stations."

antenna and/or manufacturer	gain in dBd	gain in dBi
K1WHS 24 Cushcraft 214B Yagis	24.7	26.85
WA6MGZ 16 KLM 16LBX Yagis	25.15	27.30
WA1JXN 16 KLM 17LBX Yagis	25.5	27.65
YU3WV 24 12-el J-Slots	26.0	28.15
KB8RQ 32 Cushcraft 3219 Yagis	26.95	29.10
W5UN 32 KLM 17LBX Yagis	28.25	30.40

transmission and phasing lines

Transmission line losses, even at 144 MHz, can be significant. This is especially true when long Yagis are used in large arrays where many phasing lines are required. Tradeoffs and different types of feed lines are discussed in detail in reference 10, so they won't be repeated here. Before you go too far in your antenna system plans, be sure to study the different types of transmission lines and learn how you can keep losses to a minimum.

If you can keep it well sealed from water penetration, type 9913 coax is highly recommended, especially for the phasing lines between the individual Yagis and the first power divider. Even RG 8 and 213-U coax types are usable in phasing lines if lengths are kept short. In this regard, the "back plane" configuration,[7] where the first power divider is mounted in close proximity to the feedpoint in the individual antennas, is particularly recommended .

Fifty-ohm Heliax® and hardline or Alumifoam® are highly recommended, especially for the transmitter feed line (**fig. 1**). While they're expensive, they can often be found at flea markets for reasonable prices. Especially in large arrays, very low-loss transmission lines need be used only on the long runs from the individual power dividers to the central antenna feedpoint.

Several 2-meter EMEers are using CATV hardline. (Ask super stations WA1JXN, K1WHS, and W5UN.) It's inexpensive and has very low loss, especially below 300 MHz, where it's closely specified by suppliers. Although it has an impedance of 75 ohms, it can easily be designed into the antenna system and later converted back to 50 ohms with a simple quarter-wave section of 61-ohm line.

Heretofore, it's been common Amateur practice to make phasing lines multiples of a half wavelength. This theory was debunked *in reference* 7. Since then, some Amateurs have tried using the odd number of quarter-wavelength techniques recommended

in reference 7 and have been quite pleased with the results. Lower sidelobes and higher gain were immediately evident because of the improved power distribution.

EME receivers and preamplifiers

Table 1 shows that a 2-meter EME receiver should have maximum a noise figure of 1.5 dB and a maximum bandwidth of 50 Hz. Earlier in this column, I briefly mentioned a receiver sensitivity of − 155.5 dBm. You're probably wondering how these parameters are related.

Receiver sensitivity is primarily a function of noise figure and bandwidth. If the antenna noise temperature is near room temperature (298 degrees K), the typical situation on 2-meter EME, the receiver sensitivity can be calculated using the equation shown below:

eqn. 3:

$$\text{Receiver sensitivity} = -174\ dBm + NF + 10 \log BW$$

where receiver sensitivity is in dBm, NF is noise figure in dB, and BW is bandwidth in Hz.

For example, if the receiver overall noise figure is 1.5 dB and the bandwidth is 50 Hz, the overall receiver sensitivity will be − 155.5 dBm (−174 + 1.5 + 10 log 50). But how do you get a bandwidth of 50 Hz as shown in **table 1** when your i-f bandwidth is 500 Hz? Use your ears! As the final link on the end of the receiver chain, the human ear has a typical bandwidth of only 50 Hz.[11]

If you're still not convinced, you can use a narrow i-f bandwidth. I've seen i-f filters advertised that claim a bandwidth of 125 Hz, but I'd hate to have to tune in a signal with such a narrow bandwidth — not to mention the frequency stability requirements of such a receiver!

If you don't have narrow i-f selectivity and you don't trust your ear, use an external audio filter. Some of the new solid-state active audio filters have variable bandwidth and frequency controls which will easily go down to audio bandwidths of less than 25 Hz.

Table 6. This table shows the recommended stacking distance for some of the more popular 2-meter Yagi antennas per reference 6 with updates.

antenna type	Stacking in E & H plane in wavelength		Stacking in E & H plane in inches	
W1JR short Yagi (ref. 9)	1.35	1.20	110	98
NBS 2.2 wavelength Yagi	1.55	1.40	127	115
Cushcraft 214B Jr. Boomer	1.55	1.40	127	115
Tonna (F9FT) 20116 Yagi	1.60	1.50	131	123
KLM 13LBA Yagi	1.80	1.55	147	127
CueDee Yagi	1.70	1.40	139	115
NBS 3.2 wavelength Yagi	1.80	1.35	147	111
Tonna (F9FT) 20117 Yagi	1.55	1.40	127	115
Cushcraft 3219 Boomer Yagi	1.80	1.35	147	111
NBS 4.2 wavelength Yagi	1.95	1.75	160	144
KLM 16LBX Yagi	2.00	1.75	164	144
Cushcraft 4218XL Yagi	1.95	1.75	160	144
M² Enterprizes 2M-5WL Yagi	1.95	1.80	162	147

The one major difference between a conventional VHF/UHF or hf receiver and an EME receiver lies in the external preamplifier that's usually mounted at or very close to the antenna feedpoint. This is almost always necessary for two reasons. The first is that the line loss to the shack is usually over 0.5 dB, so the weak signal is further attenuated. The second is that there are no conventional receivers with 1- to 1.5-dB overall noise figures as required in **table 1**.

First a word about preamplifiers. There are many options. Although I used only a U-310 JFET preamplifier (shack-mounted at that) to obtain my 2-meter WAS Award, I now recommend the use of a GaAsFET preamplifier mounted in a small enclosure as close to the antenna feedpoint as possible. Many preamplifier circuits — as well as commercially manufactured units — are available.

However, one mustn't get carried away with specifications. For instance, there's practically no justification for 2-meter EME preamplifier gains in excess of 25 dB; even 20 dB may be overkill. Very often I see 144-MHz GaAsFET circuits using tuned output stages. When this is done below about 1000 MHz, the circuit is almost always on the verge of oscillation. This can result in an input impedance off the Smith chart when a preamplifier is measured on a network analyzer. Instability is also evident if a preamplifier oscillates when placed in the antenna system where the impedance is not constant at all frequencies! Furthermore, excessive preamplifier gain may cause your receiver to intermodulate because of the presence of other Amateurs, fm repeaters, or even commercial fm and TV signals that often pass through the preamplifier.

At 144 MHz, I prefer GaAsFET preamplifiers with tuned input tanks and untuned outputs such as those that use a 4:1 broadband output transformer. Some recommended GaAsFET preamplifier circuits are described in reference 12. If you have any doubt about preamplifier stability, measure the forward gain and reverse isolation with a very weak signal source. If the reverse isolation isn't at least 4 to 6 dB higher than the forward gain, the preamplifier is potentially unstable.

If you use an external low-noise preamplifier as recommended above, and mount it at the antenna feedpoint, the loss and type of the transmission line between the preamplifier and the receiver usually isn't critical, since the overall gain of the preamplifier is typically 20 to 25 dB. Hence moderately lossy coax cable such as RG-8 or RG-231/U is perfectly acceptable (see **fig. 1**).

Two-meter EME receivers offer many options. A decade ago most 2-meter EMEers used a downconvert-

er or transverter followed by an hf receiver for the i-f. This setup has lots of system flexibility.

When choosing an hf i-f for EME operation, look for a receiver that has good frequency stability, a slow tuning rate (25 or less kHz per turn), frequency readout that has good resolution and accuracy, narrow bandwidth i-f options, an SSB/CW product detector, and an automatic noise blanker. An i-f bandwidth of 250 to 500 Hz is recommended, as discussed above. Some of the favorite EME i-f receivers of yesteryear were the old Collins 75A4 and the Drake R4C with appropriate modifications. More recently, the Kenwood TS 830 and TS 430 have become popular.

Many multimode 2-meter transceivers are available. Until recently, the Yaesu FT-726R was a favorite because of its built-in narrow bandwidth CW filter. Other 2-meter transceivers now offer this option. You can use a transceiver with a 2- to 3-kHz i-f bandwidth if your ears don't mind all the excess noise; better yet, follow the transceiver with an external audio filter as mentioned previously. This is the setup at one of the 2-meter super stations!

transmitters and power amplifiers

If you have either a 2-meter transverter, upconverter, or one of the new multimode transceivers, you have the basic building block for a 2-meter EME exciter. Frequency stability is important. Remember that the station trying to work you may be listening in a 50- to 100-Hz bandwidth, so any chirp or drift on your part will significantly degrade success.

Probably the biggest choice lies in deciding how to generate power. If you build a marginal station and expect to work only the super stations, a typical beginner's approach, a solid-state "brick" will probably be sufficient. Many circuits can be found in reference 13; commercial solid-state amplifiers are also available.

However, always build or buy one of the linear amplifier types. You may later use this amplifier as a driver for a high-power final. Class C or fm amplifier types often exhibit erratic power output levels when their drive levels are varied. This could make output power setting very difficult or damage a follow-up final amplifier.

There are many choices of high-power amplifiers. Remember that even 500 to 750 watts of output power is sufficient for operating 2-meter EME. There are still plenty of plumbers' delights or parallel tube finals around — especially those that use the venerable 4CX250Bs. Often available quite inexpensively, especially from Amateurs who are upgrading to the new FCC 1500-watt output power levels, they'll easily generate as much as 1000 watts of output if they're properly cooled. More information on these finals is contained in references 14 and 15. The 8874 and 3CX800A7 tubes have become popular, especially where single-tube amplifiers are preferred. Other tubes such as the 7650, 7213, and 4CX1000 are usable. Other finals are described in references 16 and 17. The most popular 2-meter EME final for generating the full legal limit is the W6PO power amplifier, which uses an 8877.[17], [18] This amplifier has excellent stability, and is conservatively rated and reasonably efficient (i.e., greater than 60 percent). Furthermore, individual components, parts kits, or even a completed amplifier using this circuit are now available.* Finally, several commercially manufactured tube type finals are now available for 2-meter operation.

azimuth and elevation rotators

Any detailed discussion of this subject would require an entire article of its own. Some of the systems presently in use on 2-meter EME range from simple single Yagis on a tropo setup to complex arrays with exotic rotating systems occupying an entire acre of land.[19] Most EMEers will simply use their own ingenuity, building a rotator according to the requirements of the station and the materials most easily pressed into service.

Reference 9 showed my simple back yard/portable array, resting on a small, ground-mounted 11-foot tower for the base. A conventional Ham-M or equivalent rotator is used for azimuth control. Elevation is set by a small boat winch mounted on the vertical mast just above a hinged plate that holds the horizontal boom. Elevation angles are measured with a hand-calibrated plate and lead weight attached to the main boom. This setup is simple and relatively inexpensive.

Several large commercial rotators are now available with accuracies approaching 1.0 degree. While separate selsyn indicators used to be common, auxiliary azimuth indicators that use a linear potentiometer are becoming quite popular now that low-cost digital voltmeters are available.

Some Europeans have cascaded two or more of the elevation rotators used for typical OSCAR antenna control. For large antenna systems, the venerable "prop pitch" motor is still alive and well. Several years ago, many different EME rotator systems were described in Eimac's *EME Notes*.[20]

polarity rotation

So far I've only touched on the subject of polarity rotation. Circular polarization would greatly improve the Faraday rotation problem on 2-meter EME, but it's very difficult to implement on large Yagi arrays. As mentioned before, circular polarization would reduce the signal levels from linearily polarized stations by up to 3 dB.

For these reasons, some Amateurs have devised polarity rotation schemes for collinears (VE7BQH) and Yagi arrays (K5GW), but describing them in detail would require discussion of mechanical considerations beyond the scope of this column. In this regard, the parabolic dish has much to offer despite its low efficiency and size. The rest of us will just have to trust our luck to the Faraday rotation present during our schedules!

---

*Gene Shea, KB7Q, 417 Staudaher Street, Bozeman, Montana 59715.

relays and control systems

The simplicity or complexity of this part of the system is a matter of personal choice. **Figure 1** shows most of the components required for a complete minimum station. Rotator cables and the like are quite straightforward.

The one area that deserves some special consideration is the antenna changeover and receiver protection relays. There are two major problems with these in EME operation. The first is the leakage or isolation of the main T/R relay. When running over 500 watts of output power, the leakage across this relay when in transmit can be sufficient to burn out your receiver preamplifier unless the isolation is greater than 50 dB. Many of the T/R relays used by Amateurs offer marginal isolation at 144 MHz. Second, the switching time on the T/R relay is critical because if the high power is applied before the relay is fully transferred, the preamplifier is again subjected to rf burnout levels.

Most of these problems can be solved if you have a short built-in time delay before rf or high voltage is applied to your final power amplifier. Additional isolation in the form of a second relay in series with the preamplifier is also recommended. This relay can be a low-power type and preferably will terminate the preamplifier input, with a 50-ohm load during transmit. If the length of the coax between the relays is 0.1 to 0.25 wavelength, it will increase isolation.[3]

These features should be wired into the station control system, with a foot switch to further control the sequences of events. Therefore, I recommend that you review the scheme and schematic of the recommended switching technique described in reference 3.

system checkout

Before you try to fire up and listen for EME signals, it's best to make sure that your system is functioning properly. If it's convenient, disconnect the preamplifier and test the antenna system for VSWR. If everything was properly installed, the VSWR should be well below 1.5:1. Then increase your power to confirm that there's no output power problem.

Next, reconnect your preamplifier and receive system. Check your receive system by pointing your antenna towards different areas of the sky. The noise level should vary as you point to radio "hot spots." Aiming your antenna at the sun — the largest hot spot — should increase the noise output of your receiver by at least 6 to 8 dB.

After peaking your receiver on the sun, sight up the antennas and verify that the sun is reasonably close to boresite. Next point your antenna away from the sun and try to measure your first sidelobes, which should be detectable but many dB below the main beam. If the sidelobes are high or the antenna doesn't boresite well, check your phasing lines for possible phase inversions.

Now try some echo testing. Send a letter or two and listen carefully for an echo. Remember that the returned signal may be up to 500 Hz above or below the transmitted signal, depending on whether the moon is approaching or leaving you, as described in reference 1. If you don't hear anything, don't be discouraged. Faraday may be unfavorable. Try again in 15 to 30 minutes.

Next listen for other EME signals. There's almost always activity on weekends and evenings whenever the moon is above the horizon at north declination. Tune between 144.000 and 144.020 and see if you find any EME signals; this is where most of the super stations congregate and where most random CQs take place.

If you don't hear any signals, activity may be low or Faraday rotation may be unfavorable. Wait a while and try again. Check the 144-MHz EME Directory for someone you can contact locally.[21] Better yet, set up a schedule with one of the active EME stations, who can usually be found on 14.345 MHz on Saturdays and Sundays between 17 and 1900 UTC on the 2-meter EME net usually MC'ed by Lionel, VE7BQH.

scheduling

This is a subject in itself which is again beyond the scope of this month's column. Many scheduling tips and recommendations can be found in references 1 and 22. Try to make schedules near perigee, when the moon is at northerly declinations away from the galactic plane, and when there are no local objects obstructing the antenna view. Perigees are always listed at the end of each month's column, and an *EME calendar appears* monthly in *VHF/UHF and Above.** Unless there are no other possibilities, don't make schedules when the moon is in the galactic plane, at the new moon phase, or when the moon is at low elevation angles (except for horizon shots where there may be no other possibilities).

When you run a schedule, it's best to follow the standard techniques and scheduling sequences that have become well established procedures. First, the scheduled frequency is your zero beat frequency. Since doppler is usually present, leave your transmitting frequency fixed and tune only your receiver until you find the desired station.

Most schedules conducted on 2-meter EME are for either one-half or one hour's duration. Each station usually transmits and receives alternately for two minutes at a time. The easternmost station generally transmits during the first two-minute period at the start of the hour. This is often referred to as "standard sequencing."

For example, if a W2 station schedules a W6 station between 1900 and 2000 UTC, the W2 station, as the eastern station, would transmit from 1900 to 1902 UTC and listen from 1902 to 1904 UTC, and so forth. If, however, the schedule is from 1930 to 2030, the W6 station would transmit first from 1930 to 1932, since sequencing is based on the hour, and with 2-minute sequencing, there are an odd number of periods in the first half of the hour.

---

*Rusty Landes, KA0HPK, "VHF/UHF and Above Information Exchange," P.O. Box 270, W. Terre Haute, Indiana 47885.

The reporting system used on 2-meter EME is different from the one used on 432 MHz and above. "T" designates detectable signals, "M" means letters or portions of calls, and "O" verifies that both call signs have been copied. Therefore, an exchange of an "O" report and appropriate "Rs" are required for a valid QSO. Never transmit an "O" report or an "R" until you have complete call sets and reports respectively, because the reporting sequence can only go forward!

Most 2-meter operators make up a standard schedule sheet with each 2-minute time block designated. They then write in all information sent and received in the appropriate time blocks; this will help if there are deep fades or partial copy, Faraday rotation problems, or if authentication is required later on.

other tips

Have someone in your area check your frequency to confirm that you're transmitting where you think you are. A secondary frequency standard such as the one described in reference 23 is recommended. Use the 2-meter EME net to make schedules or to see who's active, when they're active, and what frequency they're on. *The 144-MHz EME Directory*[21] is a *must* if you want to know what other stations are active and what equipment they use. Published monthly, *The 2-Meter EME Bulletin* includes good tips and information about the activity of other 2-meter EME stations.*

summary

So there you have it — all the necessary basic information needed to get you started on 2-meter EME. Let me know if I missed any necessary information. Some of the topics discussed had to be dealt with only briefly, but the references cited or the EME nets are excellent sources for further details or clarification. As is often the case, it sometimes takes longer to explain a

*Gene Shea, KB7Q, "2-Meter EME Bulletin," 417 Staudaher Street, Bozeman, Montana 59715.

particular item in print than to demonstrate it in a hands-on situation.

If you have only a small antenna, consider listening for EME signals in the 144.000-144.020 MHz region, especially during the EME contest on October 17-18 and November 14-15, 1987. Even if you're not ready to get started in EME, try putting up a simple antenna in your back yard and see what you can hear. Who knows — the bug might bite! See you on EME shortly!

new records

In Oregon on March 8, 1987 at 1950 UTC, Tom Hill, WA3RMX/7 (CN85PL), and Lynn Hurd, WB7UNU (CN85NH) did it again by breaking their own North American DX record on 47.040 GHz. This time they extended the distance to almost 14 miles, and again had a two-way QSO on SSB with good signal-to-noise ratios. Tom was running 3.5 milliwatts to a 28.5-inch dish, while Lynn was running just 44 microwatts to a 9.5-inch dish!

Meanwhile, as predicted in last month's column, new EME records were being made. On April 12, 1987 at 0530 UTC, Lucky Whitaker, W7CNK/5, Oklahoma City, Oklahoma (EM15FI), worked Keith Ericson, K0KE, who was operating portable in Denver, Colorado (DM79NO), on 3456.1-MHz EME *for a new worldwide EME DX record* of 498 miles. Lucky was using a 5-meter dish and 80 watts, while Keith borrowed the use of a 10-meter satellite dish and was running only 12 watts of output power! Signals were copied easily off a speaker with a 2.5-kHz receiver bandwidth!

Not content with this record, Lucky, W7CNK/5 (EM15FI), converted his setup to 5760.1 MHz. Then he completed the first Amateur two-way EME contact on that band on April 24, 1987 at 1620 UTC with Rick Fogle, WA5TNY, Grapevine, Texas (EM12KV), for a 174-mile record. Lucky was running 100 watts to his 5-meter dish and Rick was running only 25 watts to a 10-foot TVRO dish. After the initial contact, Dave Hallidy, KD5RO, jumped in, using Rick's station to give

W7CNK/5 his second 5760.1-MHz contact.

Congratulations to Tom, Lynn, Lucky, Keith, Rick, and Dave. The spring of 1987 may go down in history as one of the greatest record-breaking periods in UHF/SHF history.

important VHF/UHF events

September 5-6	International Region 1 VHF Contest, 2 meters only
September 6	EME perigee
September 10-13	Microwave Update 1987 Conference, Estes Park, Colorado (contact W0PW)
September 12-14	ARRL September VHF QSO Party
September 19-20	ARRL 10-GHz Cumulative Contest, second weekend
September 21	±2 weeks. Optimum time for TE propagation
October 3-4	International Region 1 UHF/SHF Contest, 70 cm and up
October 4	EME Perigee
October 9	Predicted peak of the Draconids meteor shower at 0900 UTC
October 10-11	Mid-Atlantic States VHF Conference, Warminster, Pennsylvania (contact WA2OMY)
October 17-18	ARRL EME Contest, first weekend
October 21	Predicted peak of the Orionids meteor shower at 0830 UTC
October 30	EME Perigee

references

1. Joe Reisert, W1JR, "VHF/UHF World: Minimum Requirements for 2-Meter EME — Part 1," *ham radio*, August, 1987, page 39.
2. Joe Reisert, W1JR, "VHF/UHF World: 220-MHz EME Requirements," *ham radio*, September, 1984, page 45.
3. Joe Reisert, W1JR, "Requirements and Recommendations for 70-cm EME," *ham radio*, June, 1982, page 12.
4. Merrill I. Skolnik, "Introduction to Radar Systems," Chapter 2, McGraw Hill, 1962.
5. Joe Reisert, W1JR, "VHF/UHF World: Determining VHF/UHF Antenna Performance," *ham radio*, May, 1984, page 110.
6. Joe Reisert, W1JR, "VHF/UHF World: Stacking Antennas — Part 1," *ham radio*, April, 1985, page 129.
7. Joe Reisert, W1JR, "VHF/UHF World: Stacking Antennas — Part 2," *ham radio*, May, 1985, page 95.
8. Joe Reisert, W1JR, "VHF/UHF World": Yagi Facts and Fallacies," *ham radio*, May, 1986, page 103.
9. Joe Reisert, W1JR, "VHF/UHF World: Optimized 2- and 6-Meter Yagis," *ham radio*, May, 1987, page 92.
10. Joe Reisert, W1JR, "VHF/UHF World: Transmission Lines," *ham radio*, October, 1985, page 83.
11. Dick Turrin, W2IMU, "Simple Super Selectivity," *QST*, January, 1967, page 48.
12. Joe Reisert, W1JR, "VHF/UHF World: Low-Noise GaAsFET Technology," *ham radio*, December, 1985, page 99.
13. Joe Reisert, W1JR, "VHF/UHF World: Medium Power Amplifiers," *ham radio*, August, 1985, page 39.
14. Joe Reisert, W1JR, "VHF/UHF World: High Power Amplifiers — Part 1," *ham radio*, January, 1985, page 97.
15. Joe Reisert, W1JR, "VHF/UHF World: High Power Amplifiers — Part 2," *ham radio*, February, 1985, page 38.
16. *The ARRL Handbook*, ARRL, Newington, Connecticut, 1987. Available from *ham radio's* Bookstore, Greenville, New Hampshire 03048. $17.95 (paperbound), $26.95 (hardbound); add $3.50 for postage and handling.
17. William I. Orr, W6SAI, *Radio Handbook*, available from *ham radio's* Bookstore, Greenville, New Hampshire 03048, for $26.95 plus $3.50 shipping and handling.
18. Robert I. Sutherland, W6UOV, "High Performance 144-MHz Power Amplifier," *ham radio*, August, 1971, page 22.
19. "Shooting the Moon," *QST* (cover), May, 1986, the W5UN EME array.
20. Bob Sutherland, W6PO, "Ideas for EME Antenna Elevation Drives," Eimac Amateur Service Note No. AS-49-11.
21. Lance Collister, WA1JXN, "The 144-MHz EME Directory," Eimac Amateur Service Note No. AS-49-37. Available upon request (enclose four first-class stamps) from Bill Orr, W6SAI, c/o Varian, Eimac Division, 301 Industrial Way, San Carlos, California 94070.
22. Joseph H. Reisert, W6FZJ/1, "EME Scheduling, When and Where," *QST*, July, 1974, page 25.
23. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Frequency Calibrator," *ham radio*, October, 1984, page 55.

ham radio

short circuits

spacing dimensions

In **fig. 2** of W1JR's April, 1987, column (page 74), the spacing dimensions listed for the fourth director, D4, of the 46-element loop Yagi do not agree with the drawing. The drawing is correct; the listing should be corrected to show the spacing for D4 as 14.1721 (TNX K5DUT).

In **fig. 6**, the length of the inductors is not shown because it is assumed that the specified enclosure will be used. If it is not used, the height of the inductor above ground should be about 1.5 inches.

pin 16, not 10

In **fig. 6** of W1JR's June, 1987, column (page 75), pin 10 on the left-hand side of U1 (between pins 12 and 13) should have been labeled as pin 16 (TNX W5YHT).

missing table

Table 1, omitted from W1JR's VHF/UHF World column in the April issue (page 55), is shown below.

Table 1. Some citizens-band type fm transceivers are available in Japan but not yet in the USA.

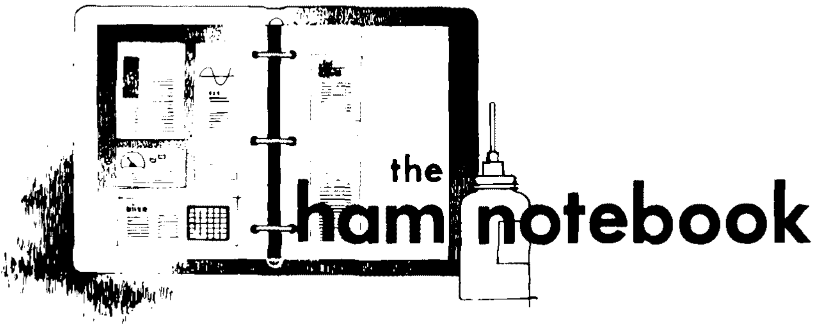
Company	Part No.	Price
ICOM	GTX	NA
Shinwa	SC-905GII	NA
Yaesu	FYA903	NA
Yaesu	FYA905A	approx. 80,000 Yen

220 Notes

In table 5 of W1JR's July, 1987 column (page 38), *220 Notes* was indicated as being issued quarterly. This is incorrect; *220 Notes* is published bimonthly. To subscribe ($5/year), contact Walt Altus, WD9GCR, 215 Villa Road, Streamwood, Illinois 60103.

20-meter travelradio

Planning to build K1BQT's compact CW transceiver (June, 1987)? Send an SASE (with 39 cents postage) to *ham radio*, Greenville, NH 03048, for a complete list of corrections.



improving the WB3CEH programmable call sign identifier

When Gene Colson, KL7YM, was constructing a new repeater for our mountain top site in Fairbanks, WB3CEH's article describing his programmable call sign identifier[1] caught my eye. The identifier appeared to be perfect for our needs. But when I began ordering the parts, I couldn't find the MC14557 64-bit shift register IC specified, and neither KL7YM/R, WB3CEH (the author's call), nor KL7XO (my own call) would fit into 64 bits.

A search through catalogs revealed a substitute for the MC14557: the CD4031, also a 64-bit shift register. A phone call to Jameco* brought several of them within a week. I cascaded two for a total of 128 bits and reversed the A and B inputs to reduce standby power consumption.

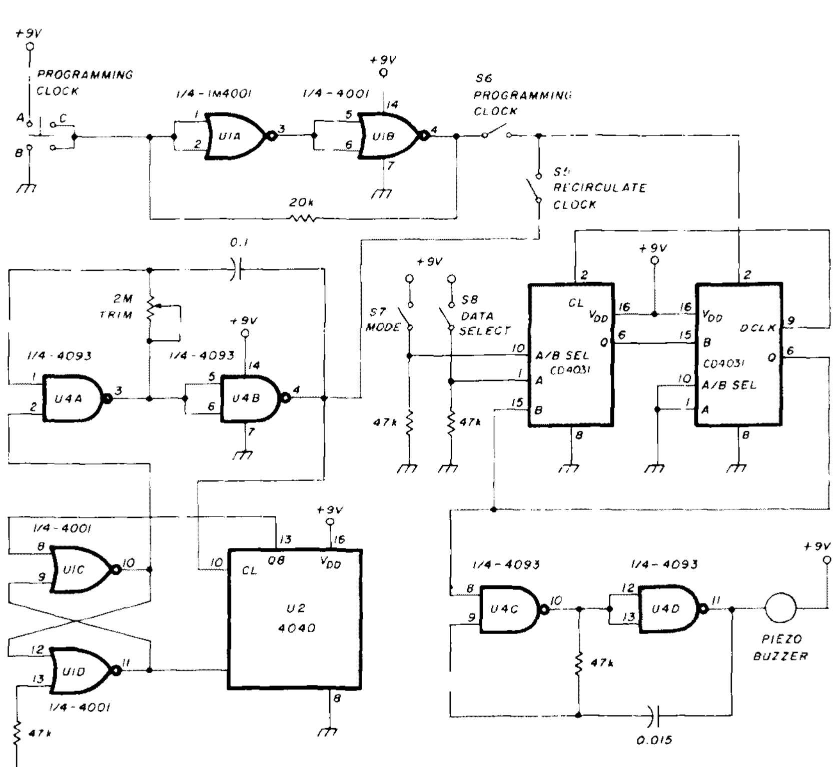


fig. 1. Modified WB3CEH programmable call sign identifier.

I built the first one. It worked, with measured current consumption of 0.0005 mA on standby, 0.17 mA running without the buzzer, and 0.55 mA with the buzzer. Over two years later, it's still on the bench in my shack — with the original 9-volt battery. KL7YM built the production model, which is still in use on the repeater.

The construction and programming instructions in the original article still apply. The schematic of the modified circuit is shown in **fig. 1**.

Steve Estes, KL7XO

reference

1. Donald G. Varner, WB3CEH, "Programmable Call Sign Identifier," *ham radio*, February, 1985, page 33.

*Jameco, 1355 Shoreway Road, Belmont, California 94002.

carpet samples in the ham shack

While shopping for new carpet several years ago, I stumbled upon a pile of 18 by 24-inch samples with nicely finished borders being sold for a dollar each. I bought several.

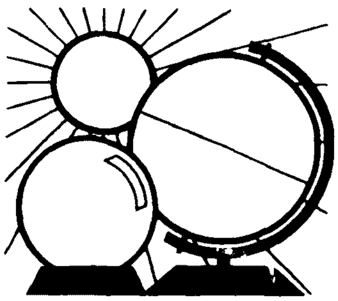
What does this have to do with Amateur Radio? Well, one sits on my workbench to protect the surface from scratches and wear. It also protects radios from scratches and dings while I'm working on them. I selected a tightly woven, light-colored pattern for this so that small screws and parts wouldn't disappear. Another sample ended up beneath my very large, heavy Qume Sprint 5 daisy-wheel printer, helping to silence its operation. Another found its home under a fairly large hf linear amp.

When you have to move something heavy (like an overstuffed filing cabinet) across hardwood or linoleum floors, try sliding two or more of these carpet samples face-down under the object; it will then slide easily across the floor without scratching.

Most carpet shops sell these samples quite reasonably. Pick up a few and see how many uses you can find for them!

Peter Bertini, K1ZJH

ham radio



DX FORECASTER

Garth Stonehocker, K0RYW

more sporadic E

Before the Sporadic E (E_s) propagation season — June through September — is over, the results of some recent experiments are worth mentioning.

An ionosonde is a low-frequency, mf-hf radar that provides information about ionospheric layers by transmitting a signal vertically and measuring the duration of its round trip.* Using an ionosonde located in Hawaii, researchers have been able to identify and measure E_s cloud formation and movement, determining the east-west, north-south, and height changes of the signal's reflection point by means of doppler frequency shift data.

At altitudes below approximately 72 miles, there's a neutral particle "sandwich"; its upper level moves in a westerly direction, while its lower level travels in the opposite direction. Collisions between the particles in these layers and gyromagnetic interaction result in vertical ion movement from below and above the region. Very thin, intense, long-lived layers develop at the specific height at which the net ion vertical velocity is zero.

These metallic ions are of meteoric origin; it is the variations in their content that accounts for E_s patch differences, locations, and diurnal behavior. These differences — in turn manifested by varying layer shape (gradient), thickness, and intensity — account for changes in the maximum frequency that can be reflected.

For a clearer idea of the magnitude of these variations, consider this: over a period of only 20 minutes, the maximum usable frequency changed from 4 to 8 MHz in a patch that was only 6 miles long. Such clouds, however, can cover areas as large as 36,000 square miles (60 × 600 miles) and last up to 2 hours, resulting in long 10- or 15-meter openings.

last-minute forecast

During the first week and the ten days of September, expect low values of flux, resulting in the lower frequency bands being best. Nighttime openings will occur on these bands on the east-west and northern paths. If the geomagnetic field is disturbed on September 1st through 4th and 24th through the 29th, expect lower signal strengths and QSB. The second and third weeks are expected to offer very good higher hf-band DX openings in southerly directions. Some of the openings may be the result of transequatorial propagation, particularly in the evening and during disturbed conditions.

The moon will be full on September 7th and at perigee on the 6th. The autumnal equinox will occur on the 23rd at 1345 UTC. No significant meteor showers are expected this month.

band-by-band summary

Six meters may have a few E_s openings around local noon, but don't count on them during this last month of the season.

Ten, twelve, and fifteen meters should provide a few short-skip openings and many long-skip openings to most southern areas of the world, especially if there is any solar flux increase during the daylight hours this month. Some of these openings will result from transequatorial propagation, mainly during disturbed conditions.

Twenty, thirty, and forty meters will support propagation from the eastern, western, and northern areas of the world during daytime and on into the evening hours almost every day. Distances to 2000 miles via long-skip or some short-skip E_s to 1000 miles per hop are usual.

Thirty, forty, eighty, and one-sixty meters are all good for nighttime DX. The bands will be open in the east soon after sundown, swing toward the north and south about midnight, and end in the Pacific areas during the hour or so before dawn. The time-and-frequency stations in England and Hawaii make good band monitors. On some nights these bands will be as good as they are during the winter DX season; on others, QRN may be a problem. Distances will be a little shorter than those mentioned above.

*Other *analog* ionosondes transmit signals obliquely and work in pairs; more advanced *digital* ionosondes generate phase and polarization information in addition to the standard amplitude data. — Ed.

SEPTEMBER

WESTERN USA

GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	20	40	20	15	15	12	12	15
0100	6:00	20	_40_	20	15	15	12	10	20
0200	7:00	20	_40_	_20_	15	15	12	10	20
0300	8:00	20	_40_	_20_	15	15	12	12	20
0400	9:00	20	_40_	_20_	20	20	12	12	20
0500	10:00	30	40	20	20	20	15	15	30
0600	11:00	40	40	20	_20_	30	15	15	30
0700	12:00	40	_40_	20	_20_	30	15	15	30
0800	1:00	40	_40_	_20_	_20_	30	20	20	30
0900	2:00	_40_	_40_	_30_	_20_	_30_	20	20	40
1000	3:00	_40_	_40_	_30_	_20_	_30_	20	20	_40_
1100	4:00	_40_	30	_20_	_20_	_30_	_20_	20	_40_
1200	5:00	_40_	20	15	_20_	_40_*	_20_	_20_	_40_
1300	6:00	30	20	15	20	_40_	_20_	_20_	_40_
1400	7:00	30	20	15	15	_40_	_30_	_30_	_40_
1500	8:00	40	20	12	15	20	_30_	20	_40_
1600	9:00	40	20	12	15	20	_30_	_20_	_40_
1700	10:00	_40_	20	12	12	20	20	_20_	_40_
1800	11:00	_40_	20	12	12	15	20	_30_	20
1900	12:00	_40_	20	15	12	15	15	20	20
2000	1:00	_40_	20	15	10	15	15	15	20
2100	2:00	_40_	20	15	10	15	15	15	20
2200	3:00	40	30	15	12	15	15	15	20
2300	4:00	20	40	20	12	15	12	12	15
		ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN

MID USA

MDT	N	NE	E	SE	S	SW	W	NW	CDT
6:00	20	40	20	15	15	12	12	15	7:00
7:00	20	40	20	15	15	12	10	20	8:00
8:00	20	40	_20_	15	15	12	12	20	9:00
9:00	30	_40_	_20_	15	20	15	12	20	10:00
10:00	30	_40_	_20_	20	20	15	12	30	11:00
11:00	40	_40_	20	20	20	15	15	30	12:00
12:00	40	_40_	20	_20_	20	20	15	30	1:00
1:00	40	_40_	_20_	_20_	30	20	20	40	2:00
2:00	_40_	_40_	_30_	_20_	_30_	20	20	_40_	3:00
3:00	_40_	_40_	_30_	_20_	_30_	20	20	_40_	4:00
4:00	_40_	30	20	_20_	_30_	_20_	20	_40_	5:00
5:00	_40_	20	15	_20_	_40_	_20_	_20_	_40_	6:00
6:00	20	20	15	20	_40_	_20_	_30_	30	7:00
7:00	20	20	15	15	_40_	_30_	_30_	30	8:00
8:00	20	20	12	15	20	_30_	20	40	9:00
9:00	30	20	12	15	20	_30_	20	_40_	10:00
10:00	30	20	12	15	20	20	20	_40_	11:00
11:00	40	20	12	15	15	20	_20_	_40_	12:00
12:00	_40_	20	12	12	15	15	_30_	20	1:00
1:00	_40_	20	15	12	15	15	20	20	2:00
2:00	_40_	20	15	12	15	15	15	20	3:00
3:00	_40_	20	15	12	15	15	15	20	4:00
4:00	30	30	15	12	15	12	15	20	5:00
5:00	20	40	20	12	15	12	12	20	6:00
	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN	

EASTERN USA

EDT	N	NE	E	SE	S	SW	W	NW
8:00	30	_40_	20	15	15	12	12	20
9:00	30	_40_	20	15	15	15	12	20
10:00	40	_40_	_20_	15	20	15	15	30
11:00	40	_40_	_20_	15	20	15	15	40
12:00	40	_40_	_20_	20	20	15	15	40
1:00	_40_	_40_	20	20	30	20	20	40
2:00	_40_	_40_	20	_20_	_30_	20	20	_40_
3:00	_40_	_40_	_20_	_20_	_30_	20	20	_40_
4:00	_40_	30	_30_	_20_	_30_	20	20	_40_
5:00	20	20	20	_20_	_30_	_20_	_20_	_40_
6:00	20	20	15	_20_	_40_	_30_	_30_	30
7:00	20	20	15	20	_40_	_30_	_30_	30
8:00	20	20	15	15	_40_	20	20	40
9:00	20	20	12	15	_40_	20	20	40
10:00	20	20	12	15	20	_20_	20	_40_
11:00	30	20	12	15	20	_30_	20	_40_
12:00	40	20	12	15	20	_30_	_20_	_40_
1:00	40	20	12	15	15	20	_30_	_40_
2:00	40	20	12	12	15	20	_20_	40*
3:00	_40_	20	15	12	15	15	20	20
4:00	_40_	20	15	12	15	15	15	20
5:00	_40_	30	15	12	15	15	15	20
6:00	_40_	40	15	12	15	12	12	20
7:00	30	40	20	12	15	12	12	20
	ASIA FAR EAST	EUROPE	S. AFRICA	CARIBBEAN S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

product REVIEW

Cushcraft 2-meter boomer

In 1979 Cushcraft introduced its 2-meter "Boomer"™ line of antennas, thus launching a new generation of long-boom, high-performance Yagis. A few years later, in response to a growing need for a 2-meter Yagi with even higher gain and a cleaner radiation pattern, Cushcraft introduced its new 2-meter Boomer 4218 XL Yagi.

This antenna is basically an enhanced NBS type Yagi. The trigon reflector, a "trademark" of the Boomer Antennas, improves the gain slightly but primarily enhances the front-to-back ratio. An extra director has been added between the driven element and the original first director for extra gain.[1] Cushcraft engineers found they *could also improve gain and radiation pattern* even more by moving the position of the original first director and extending all director lengths to compensate for errors in the original NBS designs.

The "T" match and half-wave balun used are other Boomer trademarks. Cushcraft retains the UHF connectors, which are not waterproofed, but supplies silicon grease and vinyl connector boots to keep the balun and feed line connectors relatively waterproof. I'd still prefer the use of type N connectors.

This antenna is quite well designed. The center section of the boom is a healthy 1.5 inches in diameter. The remainder of the boom is tapered but still very strong. The rigid boom support braces should prevent wind vibrations, and can be placed either above or below the main boom — a big advantage where stacking frames are used and you want to keep all vertical mast lengths to a minimum.

The trigon assembly has been completely redesigned since the earlier Boomers to considerably decrease wind loading. In fact, this antenna has a wind load that's only slightly higher than the original 2-meter 32-19 Boomer, which has over a 6-foot shorter boomlength. I'm sure the Boomer XL will withstand our New England winters.

assembly

It took about 2-1/2 hours to assemble the 4218 XL. The directions, while brief, were adequate. All directors taper downward in length as clearly shown on the assembly instructions so element lengths can be easily verified. However, the rear boom section wasn't labeled, and, naturally, I assembled it backwards! However, when *I tried to attach the trigon reflector, I noticed my* error and quickly reassembled this boom section.

As with other Cushcraft products, all holes were precisely drilled and all the pieces fit together very nicely. All the hardware — even the "U" bolts — is stainless steel, a real plus. (There wasn't a spare piece of hardware, however, so *don't lose anything during assembly!) Notice also* that there are spare holes in the brace supports and trigon assembly that don't require hardware.

Before you assemble the balun, I'd recommend that you first check the connectors to see if they're tightened into the connector bracket. All that's needed is to grasp the connectors carefully on the back side of the plate with gas pipe pliers and turn them clockwise. Also solder the tips of the crimp type connectors used on the coax balun. Don't forget to apply the silicon grease provided, but only to the connector threads.

After final assembly, check all dimensions carefully, especially the boom sections and element lengths as shown on the diagrams provided. Next, mount the antenna on a 7- to 10-foot high mast or tower and test the VSWR using a 5- to 10-foot transmission line between the antenna and the VSWR meter. This test is highly recommended because it will often catch any assembly problems before the antenna is mounted in a hard-to-reach spot on the top of a tower. If desired, you can also take a few minutes to adjust the T-match strap position to minimize the VSWR at your favorite operating frequency.

test results

The 2-meter Boomer 4218 XL has a clean radiation pattern with high gain per unit boomlength.[2] From on-the-air tests I made, supplemented with computer analysis, a gain of 14.3 dBd was measured. This is as high or higher than any of the competition's antennas. VSWR measured at 144.2 MHz was less than 1.2:1 as specified, so I didn't even have to adjust the T-match! The measured VSWR was less than 1.5:1 from 144 through 144.8 MHz.

One final recommendation: during the manufacture of these antennas, an oily film apparently develops on the elements. This normally isn't a problem, but before it wears off, rain droplets may cling to the ends of the elements, thereby degrading the radiation pattern. So I'd recommend cleaning the ends of the elements with acetone or an equivalent solvent before assembly.

If you use a single 2-meter Boomer 4218 XL Yagi, it will probably work best mounted clear of other antennas. If this isn't possible, try to mount it at least one-half wavelength or at least 40 inches away from any other antennas on the same mast.

These antennas will stack very well; four should make a great 2-meter EME array. Cushcraft recommends 13 1/2 feet in the E (horizontal) plane and 12 1/2 feet in the H (vertical) plane. From my stacking experience, I think that these

are very close to optimum.[3] If you do stack these Yagis, make sure not to flip them over or invert the feedlines.

Priced at about $150.00, this antenna is definitely recommended for the serious 2-meter operator. The boom is very long — almost 29 feet, which is quite large by VHF standards, so it isn't recommended for the fainthearted. However, this is a necessary evil if high gain on a single boom is desired. The beamwidth of a single 4218 XL is about 26 degrees, with the first side lobe down at least 16 dB. I'd strongly endorse this antenna for 2-meter tropo and EME operation.

For information, contact Cushcraft Corporation, 48 Perimeter Road, Manchester, New Hampshire 03108.

— W1JR

references

1. Stanley Jaffin, WB3BGU, "Applied Yagi Antenna Design Part 6," *ham radio*, October, 1984, page 89.
2. Joe Reisert, W1JR, "VHF UHF World: Stacking Antennas Part 1," *ham radio*, April, 1985, page 129.
3. Joe Reisert, W1JR, "VHF UHF World: Yagi Facts and Fallacies," *ham radio*, May, 1986, page 103.

220-MHz base station xcvr

ICOM has introduced the first 220-MHz base station transceiver, the IC-375A, a deluxe all mode radio that covers 216-230 MHz and has 99 tunable full-function memories, passband tuning, a notch filter, a noise blanker, a built-in SWR bridge, semi- or full CW break-in, a multi-function meter, "velvet touch" tuning, and an easy-to-read amber LCD readout with variable backlight. Four scanning systems are available: band, programmable, plus mode and memory scan with selectable lock-out that scans 99 memories in 5 seconds. All subaudible tones are built-in; the actual subaudible frequency is displayed. Standard repeater splits are built-in and odd splits are programmable.

For details, contact ICOM America, Inc., 2380 116 Avenue N.E., P.O. Box C-90029, Bellevue, Washington 98009-9029.

Circle #301 on Reader Service Card.

new high-powered VHF amplifiers

The new HL-250V25 high-power VHF amplifier for 2 meters from Tokyo HY Power Labs, Inc., features a special combination of two separate modules, each capable of delivering over 125 Watts. It also provides an internal GaAs FET preamplifier for pulling in weak signals.

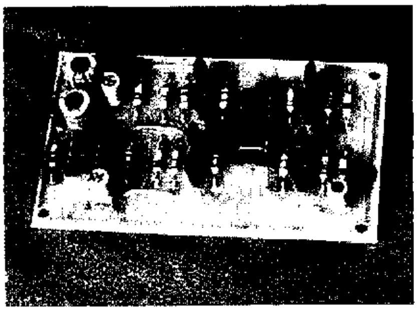
Priced at $459.95, the HL-250V25 requires 13.6 Vdc at 38 Amps maximum for power output of 250 Watts. For information, contact Encomm, Inc., 1506 Capital, Plano, Texas 75074.

Circle #303 on Reader Service Card.

active audio CW filter

The CW-1 Active Audio CW Filter is BEL-TEK's latest addition to its line of kits. The CW-1 eliminates QRM for easier copying and easily connects between your transceiver and speaker. The CW-1 has three selectable bandwidths (90, 130, and 200 Hz), with a center frequency of 800 Hz.

Priced at $19.95, the CW-1 measures 2 × 3.4 inches and can be powered by a 9-volt battery.



For more information, contact BEL-TEK, P.O. Box 125, Beloit, Wisconsin 53511.

Circle #304 on Reader Service Card.

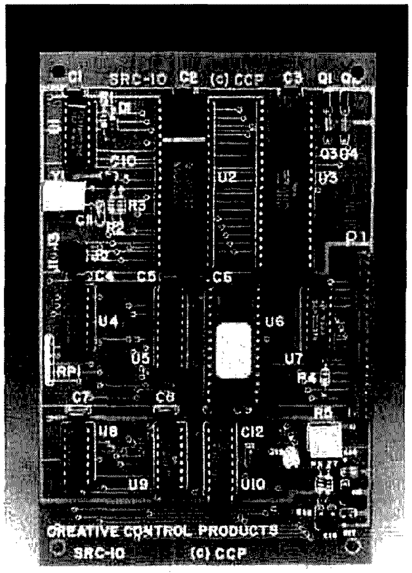
repeater control board

The latest additions to the Creative Control Products line are the SRC-10 smart repeater control board and the PI-10/S link synthesizer board. The SRC-10 is a low-cost, low-power, self-contained microprocessor-based repeater controller. All repeater functions have been incorporated onto a 4 × 6-inch G-10 glass epoxy printed circuit board with one interfacing connector for ease of installation and reliability.

Priced at $149, the SRC-10 controller provides up to seven buffered auxiliary function control outputs selected remotely via a three-digit DTMF command. The SRC-10 controller responds with a Function Complete tone after each valid DTMF command. In addition to the Function Complete Tones are Auxiliary Function Tone Responses to indicate an ON or OFF condition. Courtesy Tone Responses are also available to indicate

NEW products

repeater or link COS activity. There's also a lock command that's especially useful for dealing with jammers or hackers; when selected, the controller ignores all DTMF commands until the unlock command is received.



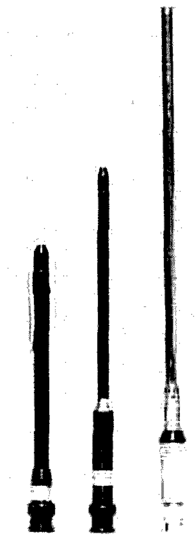
With the optional PI-10/S synthesizer board ($39), the frequency and offsets of the link radio may be programmed remotely. After the frequency and offset is sent in serial format from the controller, it is converted into parallel outputs to interface with the link radio's frequency synthesizer. A readback command can be used to verify the link frequency.

For details, contact Creative Control Products, 3185 Bunting Avenue, Grand Junction, Colorado 81504.

Circle #302 on Reader Service Card.

three new antennas

MFJ Enterprises, Inc. has announced the release of several new antennas. The MFJ-1710 ($9.95) is a 3/8-wave, 2-meter telescoping antenna with BNC. It comes with a convenient pocket clip and measures 5-3/4 inches collapsed and 24-1/2 inches fully extended.



The MFJ-1712 ($14.95) is a 1/4-wave 20-meter and 5/8-wave 440-MHz telescoping antenna with BNC. It measures 7-1/4 inches collapsed and 19 inches fully extended.

MFJ-1714 ($16.95) is a 1/2-wave 20-meter telescoping antenna with BNC. This unit is an end-fed, 1/2-wave dipole, which is shorter, lighter, has more gain and places less stress on the connector than a 5/8-wave mounted on a handheld. When collapsed, it performs like a rubber duck.

These MFJ products come with a double guarantee: order any product from MFJ. Try it. If you're not satisfied — for any reason — return it within 30 days for a complete refund (less shipping). MFJ products are also covered by a one-year unconditional warranty, so customers are assured of continued service.

For more information, contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, Mississippi 39762.

Circle #305 on Reader Service Card.

hardware and software for Yaesu transceivers

The HF-Link line of hardware and software products provides a unique approach to controlling the Yaesu FT-980 and FT-757GX hf transceivers. Designed to interface with the Atari 8-bit family of microcomputers, the new products allow control of these transceivers with a standard joystick and eliminate the need for typing operating commands. They provide an accurate, on-screen graphic depiction of the tran-

sceiver's operational status; memory channel scanning at rates determined by the user; rapid updating of station logs; unlimited disk storage of log and memory channel data files; and performance of other functions even when the operator is absent.

For details, contact Wald-Easterday Associates, Inc., P.O. Box 16165, Columbus, Ohio 43216.

Circle #306 on Reader Service Card.

new antenna catalog

A new full-color, 12-page brochure shows Centurion International's complete line of antennas for portable radios, pagers, and cordless telephones, as well as accessory adaptors and cable assemblies. Included is a connector identification chart and list of radio models on which each style is used, making it easy to order the correct antenna.

For a free copy, contact Centurion International, Inc., P.O. Box 82848, Lincoln, Nebraska 68501.

Circle #307 on Reader Service Card.

satellite receiver/ descramblers

The new 2500R integrated satellite TV receiver and descrambler from General Instrument's VideoCipher Division combines the features and benefits of a receiver and a descrambler in a single unit. With the 2500R, consumers can purchase authorization to receive the descrambled signals of nine premium television programmers currently scrambling their satellite broadcasts (another 20 programmers intend to scramble their signals by the end of 1987).

Priced at approximately $1250, the VideoCipher 2500R, with wireless remote control, uses advanced circuitry that provides a threshold improvement of up to 2 dB over other receivers, reduces "sparklies," and provides crisper images.

Other key features include two methods of parental supervision for controlling access to specific programming, a built-in terrestrial interference filter optimized for use with the VideoCipher II descrambler, programming for 24 C-band and 32 Ku-band channels, and digital stereo audio. An optional antenna positioner power supply allows users to program up to 21 satellites in memory and to program 10 channels on any satellite for instant recall by remote control.

The VideoCipher® II 2400R, a new lower priced ($1050) integrated unit comes standard with wireless remote control, two methods of parental program supervision for controlling access to selected programming, fully programmable antenna positioner, programming for 24 C-band and 32 Ku-band channels, and digital stereo audio.

NEW products

For further information, contact General Instrument, Videocipher Division, 6262 Rusk Road, San Diego, California 92121.

Circle #309 on Reader Service Card.

circuit analysis program for the C-64

The new ALADYN-64 interactive circuit analysis program from Interceptor Electronics allows users to design linear ladder networks, commonly found in rf amplifiers and filters, on the Commodore 64 computer.

Formatted to simulate a vector network analyzer, the program permits the designer to select the frequency range over which the circuit will be tested. Output is in the form of S parameters on either a rectangular grid or Smith chart.

A disk drive is required; a printer is optional. The program, priced at $59.95 (postpaid) is written in BASIC and compiled for increased speed of operation.

For further information, contact Interceptor Electronics, Route 1, Box 439, Round Hill, Virginia 22141.

Circle #308 on Reader Service Card.

communications software packages

Kalt & Associates offers packet radio and multi-mode traffic handlers and other users several software packages for IBM and IBM-compatible PCs. Their Digipac II, for example, includes such exclusive features as full-screen editing (split-screen mode), full NTS traffic macro system, an alert alarm system with visual/audible/printer and disk control modes, "make-your-own" pop-up help screens, multi-sound alarms, "format-your-own" time/date/operator stamp, and user-defined function keys. Also available are full message forms, a pop-up help system, split screen, ASCII/binary file transfers, macro keys, macro files, DOS shell, character and line buffer mode, auto line-feed, disk logging, and other features. Scrolling function keys eliminate all the confusing ALT/commands common to other programs. Digipac II is priced at $49.95 plus $3.00 postage ($8.00 foreign).

The Message Form system is available independently for users who already have other communications software; it's priced at $29.95, with the same shipping rates.

For information, contact Kalt and Associates, 2440 E. Tudor Road, Suite 138, Anchorage, Alaska 99507.

Circle #311 on Reader Service Card.

ATV transmitter

The TX70-1 1-watt, 70-cm (420 to 450 MHz) ATV transmitter is a small (6 × 5.2 × 2.5-inch) unit designed to enable Technician or higher-class Amateurs to transmit live-action color or black and white composite video and audio from cameras, VCRs, or computers to other hams. The TX70-1 is a companion to the TVC-4G receiving downconverter.

The TX70-1 contains the improved KPA5-c transmitter board, which added a video monitor output of the actual modulated rf. Priced at $229 for single frequency, (a second crystal is available for $15), the unit has provisions for switching between two frequencies (the most popular frequencies are 426.25, 434.0 and 439.25). A switch is also provided to select video and audio input from either the 10-pin VHS-type home color cameras, or phono jacks for other cameras, VCRs, computers, or any composite video and line level audio source. A mic jack and "push-to-look" jack is available for low-impedance dynamic microphones and transmit/receive switching. The external power requirement is 12 to 14 Vdc at 500 mA plus whatever the connected 12-volt camera draws. The antenna connector is a type N, and a BNC outputs to the receiving downconverter from the built-in rf T/R relay.

The shielded cabinet of the TX70-1 is small enough to be carried in a knapsack for portable operation. Theoretical snow-free, line-of-sight DX using the 1-watt TX-70-1, TVC-4G downconverter and six-element KLM 440-6X beams is 5 miles. For greater DX with mobile or base applications, the output power and the sync stretcher in the video modulator of the TX70-1 matches the 50-watt Mirage D24N amplifiers' linear input vs. output range.

Licensed Amateurs can contact P.C. Electronics, 2522 Paxson Lane, Arcadia, California 91006, for more information and a complete catalog of this and other ATV products for the 70, 33, and 23 cm bands.

Circle #310 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance.** No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

SMART BATTERY CHARGER for gell cells or lead acid batteries, by Warren Dion, W1BBH. See June '87 QST Magazine for circuit details. Complete kit, nothing else to buy, only $49.95 plus $3.50 s/h. *Order #150-KIT.* A & A ENGINEERING, 2521 W. LaPalma, Unit K, Anaheim, CA 92801. (714) 952 2114.

WANTED: WW2 Transceiver BC 654 (SCR 284) and PE-103 dynamotor. Also 1947/48 issues of Radio Craft and Radio & TV News magazines. E. Bircher, 108 Troy Drive, Slidell, LA 70461 (540) 649-7425.

FULL NTS TRAFFIC MESSAGE FORMS FOR PACKET OR RTTY on your IBM PC. MESSAGE-PAC works with any communications program to give you full Message Forms and formatted script/macro command files, ready to transmit. This is the one you've been waiting for. With user defined Pop-Up Help & Selection System that no one else offers. Can Pre Load forms from disk. Only $29 95. DEMO DISK for $2.00. Write for information. Kalt and Associates, 2440 E. Tudor Rd. Suite 138, Anchorage, AK 99507 907-248-0133. Charge Cards accepted

ELITE - CODE PROGRAMS. Apple II+/c/e/GS C 64/128. 37 *modes. Graphics, wordprocessor, menus, lessons, speed* techniques, drill, practice, print, teach, view modes: 1-100 WPM, variable sound, character, word spacing, and more. $49 95 Check/MO COD's add $2. Other versions ($14 95 - $44 95). $3.50 demo disk gives $2 off next purchase. Write: LARESCO, POB 2018, 1200 Ring Road, Calument City, IL 60409 1-312-891 3279

ANALOG AND RF CONSULTING for the San Francisco Bay area. James Long, Ph.D N6YB (408) 733-8329.

TEST EQUIPMENT WANTED. Don't wait — we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at Skagitronics Co. (800) 356-TRON.

"HAMLOG" COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7-band WAS/DXCC. Full features. Apple $19.95, IBM or CP/M $24.95. KA1AWH POB 2015, Peabody, MA 01960.

RV OPERATORS are invited to check in Sun 2 PMC, 14.240 ±5. Tues, Thurs 8 PMC 3.880 ±5. Good Sam RV Net. Info SASE KJ4RO

CHASSIS, CABINET KITS. SASE K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117 (203) 521 5280.

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photo-documentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825 ($14 95 plus $1 50 S&H).

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

DIGITAL AUTOMATIC DISPLAYS for FT-101's, TS-520's (DG-5 clone), Collins, Drake, Swan, Heath and all others. Six 1/2" digits. 5" wide by 1-1/4" high metal cabinet. Reads receive and transmit frequencies. Send $2.00 for information and receive a $30.00 discount. Includes accuracy comparison of the simple "BCD" readouts, found in new radios, against our "Calculating Frequency Counter" readouts. Please be specific. GRAND SYSTEMS, POB 2171, Blaine, Washington 98230

WANTED Manuals and Cables for type RBM-3 Rcvr, June 1942 and CCT-20086 power unit. D. Palmer, W6PHF, 638 Benvenue Avenue, Los Altos, CA 94022.

BACK ISSUES HR Magazine from Vol. 1 No. 1 thru 1986, except 2 issues. $150 for all postpaid. Also PopTronics, RE, 73 back to 1961. $15 00/full year. Write with your needs. Bill Fossman, 632 Wetmore, Everett, WA 98201

COMMODORE REPAIR. We are the largest and oldest service center in the country. (eg. C64 repair-$39.95). 72 hour turn around. Call toll Free 1-800-642-7634 (outside NY: 914-356-3131. Kasara Microsystems, Inc., 33 Murray Hill Drive, Spring Valley, NY 10977

COMMODORE CUSTOM CHIPS for C64/128 Computer/Peripherals at low prices. 24 hour delivery. #6510-$9 55, #6526-$9.95, #6567 $14.75, #6581 $12.85, PLA $10.95, 901 ROMS at $10.95 each, C128 ROMS-$39.95 (set of 3) and many others..."THE COMMODORE DIAGNOSTICIAN". A complete diagnostic reference chart for fixing Commodore computers, etc. An absolute must for those who want to fix their own computers and save money and down time. $6.95 plus postage...HD Power Supply for C64 $27.95. Send for complete chips/parts catalog. Kasara Microsystems, Inc., 33 Murray Hill Drive, Spring Valley, NY 10977. 800-248-2983 (outside NY) or 914-356-3131

MARCO: Medical Amateur Radio Council, Ltd, operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc) invited to join. Presently over 550 members. For information write MARCO, Box 73s, Acme, PA 15610.

TUBES FOR SALE. New and used, old and current, 25 cents and up. Send list for quote. Ted Youngman, 2225 Vigo Street, Lake Station, IN 46405

HAM LICENSES SUPEREASY. Cut exam preps 50 percent. All classes. Free catalog. SASE. Bahr, 2459 HS Temple, Palmbay, FL 32905

XEROX 800 Electronic Typing System technical information or *schematics needed. Terry Thompson, Box 935, Dania, FL* 33004-0935 (305) 920-1909

HOMEBREW PROJECTS LISTS. SASE. WB2EUF, Box 708, East Hampton, NY 11937.

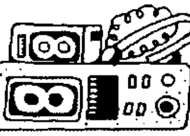
RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: *Receiving, transmitting, microwave... all* types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224 (213) 774 1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST *EQUIPMENT* $1 25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

SATELLITE DISTRIBUTOR offers lowest prices on Winegard 10 ft. UPS shippable antennas, KU-LNB's 70 MHz Down Converters, and new IQ 160 boards. Best deals on MSE LNA's and LNB's, Starcast receivers, and actuators for Arunta and IQ-160. Master Card & Visa accepted. E.S.M., Inc., 1-800-457 0060 or 314-343-7745.



COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC. ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY

CONNECTICUT: November 15. SCARA Indoor Ham Radio and Computer Flea Market, N. Haven Park and Recreation Center, 7 Linsley St, N. Haven. Sellers admitted at 7 AM; buyers from 9 AM to 3 PM. Tables are $10 in advance, $15 at the door. General admission $2 per person. Talkin on 146.61 MHz. Reservations for tables must be prepaid by November 4, 1987 and no reservation by phone. For information or reservations SASE to: SCARA, POB 81, N. Haven, CT 06473 or call Brad at (203) 265 6478 between 7 PM and 10 PM.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.

OHIO: September 27. The Cleveland Hamfest Association's annual Hamfest and Computer Show, Cuyahoga County Fairgrounds, Berea. Doors open 8 AM to 4 PM. Early setup 6 AM. VE exams 9 AM. Tech forums and non ham activities all day. Talk in on 146.52. Admission $3.50 advance; $4.00 at the gate. Inside tables $10. Outside flea market $4 00. Saturday night banquet. For more information write C.H.A., POB 81252, Cleveland, OH 44181 0252.

ILLINOIS: September 12. The Northern Illinois DX Association invites all Amateurs to attend the 35th annual W9DXCC DX Convention, Holiday Inn, 1250 Roosevelt Road, Glen Ellyn. For information and registration: Howie Huntington, K9KM, 65 South Burr Oak Drive, Lake Zurich, IL 60047.

NEW JERSEY: September 20. The South Jersey Radio Association, the oldest continuously operating radio club in the US, will hold its 39th annual Hamfest. Pennsauken Senior High School, Rt 73 and Remmington Ave, Pennsauken. 8 AM to 2 PM. Tickets $3/gate; $2.50/advance. Sellers $5 per space plus admission. VE testing all classes. Registration 9:30 AM. Refreshments available. Talk in on 145.290. For more info or tickets contact Fred Holler, W2EKB, 348 Bortons Mill Rd, Cherry Hill, NJ 08034 (609) 795-0577.

NEW JERSEY: September 13. The DeVry Tech ARC will have a Ham Radio/Computer flea market, school parking lot, 479 Green Street, Woodbridge. 9 AM to 5 PM. Vendors setup 7 AM. Sellers $3/per car space. 2 free spaces for non profit organizations. Buyers admitted free. For information call Linda (201) 634-3460 days and Frank, WB2JKU (201) 787 0818 evenings.

OREGON: September 26 27. The Walla Walla Valley ARC will hold its annual Hamfest, Oregon Community Building in Milton-Freewater. 8 AM to 5 PM. Tables and admission FREE. Exams both days. Walk-ins accepted. For more information contact Bernie Frazier, WA7CBX, 610 S. First Avenue, Walla Walla, WA 99362 or phone (509) 529-9879.

MINNESOTA: September 26. The Viking ARS will host its 17th annual Swapfest. Waseca High School, Waseca. Doors open 8 AM. Talk in on 34/94. Formore information contact VARS, POB 3, Waseca, MN 56093.

CONNECTICUT: September 13. The Candlewood ARA's annual Flea Market, Danbury Elks Club, 346 Main Street, Danbury. 9 AM to 3 PM. Dealers 8 AM. Admission $3. Tables $8. Tailgating $5. Talk in on 147.72/12. For table reservations send check or MO to CARA c/o Gene Marino, 31 Valley View Rd, Newtown. CT 06470 or call Gene at (203) 426-8852.

GEORGIA: September 27. The Lanierland ARC will hold its 14th annual Hamfest. New Location- Georgia Mountain Center near Holiday Inn, Gainesville. 8:30 AM to 3 PM. VE exams 9 AM. Free admission. Free tables for dealers registering early. Talk in on 146.07/ 67. Contact Phil Loveless, KC4UC, 4949 Red Oak Drive, Gainesville, GA 30506 (404) 532-9160.

ALABAMA: September 12 and 13. The Mobile ARC sponsored Hamfest, Texas Street Recreation Center, Mobile. Doors open 9 AM. Admission $2.00 for both days. Dealers, swap tables, non-ham activities, free parking. Also free overnight parking for SCRV's. Hospitality room Saturday night. Talk in on 146.22/82. For table reservations write MARC, POB 7232, Mobile, AL 36607. Phone N4MFQ (205) 471-4717 or KB4JET (205) 865-4404.

CONNECTICUT: September 27. The 5th annual Natchaug ARA giant flea market, Elks Home, 198 Pleasant Street, Willimantic. Starts 9 AM. Dealers 8 AM. Admissin $2. Under 16 free. Advance inside tables $5.00. At the door $7.00. Outside tailgating $5.00/up. ARRL/VEC exams for all classes. Talk in on 90/30 and 52. For information Ed Sadeski, KA1HR, 49 Circle Drive, Mansfield Ctr (203) 456-7029 after 4 PM.

IOWA: October 4. Southeast Iowa Hamfest, sponsored by the Muscatine and Iowa City Radio Clubs, West Liberty, Iowa Fairgrounds. Gates open 7 AM. Tickets $3/advance and $4/gate. Saturday night all-you-can-eat weiner roast, hay rides, flea market and fox hunt. Talk in on 146.31/.91, 146.25/.85 and 146.52. For information KA0Y, Ken, (319) 648-5037 or KE0Y, Tom, (319) 264-3259.

MISSOURI: September 27. The St. Peters ARC will hold its third annual Swapfest, Golden Triangel Park in St. Peters. 6 AM to 2 PM. Admission $1.00 to buy or sell. Expanded flea market and parking areas. Food and beverages available. For more information contact Jason Zwyers, KA0INR, 1084 Crestwood Lane, O'Fallon, MO 63366.

NEW YORK: September 20. LIMARC ARRL Long Island Hamfair, New York Institute of technology, Rt 25A, Northern Blvd, Old Westbury, NY. General admission $3.00. Sellers 7:30 AM. Buyers 9 AM. Outdoor tailgating, no reservations. Sellers car space $5. For more information Hank Wener, WB2ALW (516) 484-4322 evenings.

GEORGIA: September 20. Augusta Amateur Radio Club will hold its annual Hamfest, Julian Smith Casino, Lake Olmstead Park, Augusta. 9 Am to 3:30 PM. Tickets $2.00 at Hamfest. Talk inon 146.34/94. For more information N4JA (404) 790-7802.

MICHIGAN: October 25. The Southwest Michigan AR Team and the Kalamazoo ARC are sponsoring the 5th annual Kalamazoo Hamfest. New larger location - Kalamazoo Central High School, 2432 N. Drake Road. 8 AM to 4 PM. Walk in VE testing. Admission $2/advance, $3/door. Tables $6. Send requests and check with SASE by September 28 to Jim Hastings, Kalamazoo Hamfest, 1813 Greenbriar Drive, Kalamazoo, MI 49008.

PENNSYLVANIA: October 10-11. The Pack Rats (Mt. Airy VHF ARC) invites all Amateurs and friends to the 11th annual Mid-Atlantic VHF Conference, Warrington Motor Lodge, Rt 611, Warrington, PA and our16th annual Hamarama October 11 at the Bucks County Drive-In Theater, Rt 611, Warrington, PA. Advance conference registration $5; $6 at the door (includes admission to the flea market). Send to Hamarama '87, POB 311, Southampton, PA 18966. Admission to the Flea Market $4. per person; $7 per carload. Selling spaces $6/each. Bring tables. Gates open 6 AM rain or shine. For information Pat Cawthorne, WB3DNI (215) 672-5289.

NEW MEXICO: September 26-27. The Northern New Mexico ARC's 4th annual Hamfest, Camp Stoney, 8 miles east of Santa Fe. 8 AM to 3 PM. Forums, tailgate flea market, dealers and Sat. AM VEC exams. Also non-ham programs. For more information SASE to bob Norton, N5EPA, Rt. 3, Box 95-15, Santa Fe, NM 87505.

NEW YORK: September 12. Saratoga County R.A.C.E.S. Association's 2nd annual Hamfest, Saratoga County Fairgrounds, Ballston Spa. 9 AM to 5 PM. Forums, packet demos, 2m foxhunt, contests and more. Admission $3 includes outside selling space. Inside space $3/8 table. Talk in on 147.00 or 147.24. For more information N2FEP, Dave Atwell, Box D15, RD 5, Ballston Spa, NY 12020.

PENNSYLVANIA: September 12. The W3PIE Uniontown ARC will hold its 38th annual GABFEST, old Pittsburgh Rad, Uniontown. Pre-registration $3 each or 2/$5. Free parking, free swap and shop setup with registration. Talk in on 147.045/645 and 144.57/145.17. For more info John T. Cermak, WB3DOD, POB 433, Republic, PA 15475 (412) 246-2870 or 246-9383.

WASHINGTON, DC. September 27-29. The annual convention of the Microwave Communications Association, Ramada Renaissance Hotel. For information: Elena Selin, 2000 L Street NW, Suite 200, Washington, DC 20036. (301) 464-8408.

COLORADO: September 27. TheBoulder ARC will sponsor its annual BARCFEST Swap Meet, National Guard Armory, 4750 North Broadway, Boulder. 8 AM to 3 PM. $3. donation. Tables $3. VE tests start 9:30 AM. Food and refreshments available. For VE test info only Barbara McClune, N0BWS, 5338 Spotted Horse Trail, Boulder, CO 80301 (303) 530-1872. For BARCFEST info Dale Scott, KA0QPV, 304 E. Cleveland St, Lafayette, CO 80026. (303) 665-2364.

NEW HAMPSHIRE: October 10. The Hosstraders will hold their Fall Tailgate Swapfest, Deerfield Fairgrounds. Admission $2 per person. Sellers included. Wheelchair accessible. Friday night camping at nominal fee (after 4 PM only). Profits benefit Shriners' Hospitals. Our May 1987 donation was over $8,000! For map or info SASE to Norm Blake, WA1IVB, RFD Box 57, West Baldwin, ME 04091.

NEW YORK: September 26. Orange County ARC's 2nd annual Hamfest and Computer Fair, John S. Burke Catholic High School, Fletcher Street, Goshen. Donation $2. Indoor tables $5 each admits one. Outdoor spaces $3 each, admits one. Talk in on 146.76 repeater. For information and reservations: Barbara Christopher, N2AWI, Box 447, RD 2, Wallkill, NY 12589.

NEW YORK: September 26. The Elmira ARA will hold its 12th annual International Hamfest, Chemung County Fairgrounds. 6 AM to 5 PM. Outdoor flea market, indoor dealer displays, breakfast and lunch served on the premises. Tickets available at the gate or from Steve Zolkosky, 118 East 8th Street, Elmira Heights, NY 14903.

NEW YORK: September 12. Ham-O-Rama 87, the Niagara Frontier International Hamfest and Computer Show sponsored by the 5 Amateur Radio clubs on the Niagara Frontier. Niagara Falls Convention Center just north of Buffalo. Tickets $3.50 before August 21; $5.00 at the gate. Children under 12 admitted free. New equipment, video displays, non-technical programs, flea market. Parking facilities for the handicapped. Many nearby attractions. For information contact Bernie Norman, POB 352, Cheektowaga, NY. (716) 877-3780.

ILLINOIS: September 20. "OPEN HOUSE World of Amateur Radio" will be conducted by the Chicago ARC, North Park Village, 5801 N. Pulaski, Chicago. 11 AM to 5 PM. For information call 545-3622. Novice class license seminar starts September 28 at 7:30 PM for 10 weeks.

TEXAS: September 19-20. The annual WARS Hamfest, Wichita Falls Activity Center, 10th and Indiana Streets. 8 AM to 4 PM Saturday and 8 AM to 2 PM Sunday. Commercial displays, computer goodies, homebrew contest, large inside flea market. Advance registration $6 by September 16. At the door $7. Swap tables $5 each. VE exams 1 PM Saturday. Walkins accepted. Talk in on 74/14, 34/94, 449.30/4.30. Mail prregistration and table request with check to WARS Hamfest, POB 4363, Wichita Falls, TX 76308.

NEW YORK: October 4. The Yonkers Amateur Radio Club's Electronics Fair and Giant Flea Market, Yonkers Municipal Parking Garage, Nepperhan Avenue and New Main Street, Yonkers. 9 AM to 4 PM. Giant Auction 2 PM. Live demos all day. Free coffee all day. Admission $3. Children under 12 free. Sellers $7 per parking space, admits one, bring own tables. For further information call (914) 969-1053.

MASSACHUSETTS: October 10. The annual meeting and banquet of the New England DXCC Association will be held at the Masonic Lodge in historic Concord. Meeting 2 PM. Banquet 6:30 PM. The group is celebrating its 35th anniversary and will have a special program featuring recent DX-Peditions by some members to the Ivory Coast and senegal.

MASSACHUSETTS: MIT Tailgate electronics, computer and Amateur Radio Flea Market, Albany and Main Sts, Cambridge. 9 AM to 4 PM. Admission $1.50. Free off-street parking for 500 buyers. Sellers $5 per space includes 1 admission. Setup 7 AM. Call (617) 253-3776. Mail advance reservations by September 10 to MITUHFRA c/o 4 Madison Street, Belmont, MA 02178. Talk in on 146.52 and 449.2/44.2 pl 2A W1XM/R.

MICHIGAN: September 19. Grand Rapids Amateur Radio Association will host its annual Swap & Shop, NEW LOCATION - West Cathkolic High school, 1801Bristol NW, Grand Rapids. Doors open 8AM. Tickets $3. Tables $4 each. No trunk sales this year. Talk in on 86/26 and 224.64. For table reservations or information call Don Hazelswart, KA8BCI (616) 363-0649 or write POB 1248, Grand Rapids, MI 49501.

WISCONSIN: September 20. The Tri-county ARC, W9MQB, will hold its "Fall-Fest", Blackhawk Technical Institute, Hwys 51, between Beloit and Janesville. 7 AM to 3 PM. $2.00 per person. Bring your own tables for flea market. Talk in on 145.45 and 146.52. For more information: Carl Searing III, KW9W, 249 N. Tratt Street, Whitewater, WI 53190.

CALIFORNIA: September 19. The Sonoma County Radio Amateurs will hold their fifth annual Ham Radio Flea Market, Sebastopol Community Center, 390 Morris Street, Sebastopol. 8 AM to 2 PM. Free admission and parking. Tables $7/door; $5/advance. Vendor setup 7 AM. VEC exams, radio clinic, exhibits, refreshments, auction. Talk in on 146.13/73. For tickets and information write SCRA, Box 116, Santa Rosa, CA 95402.

OPERATING EVENTS

"Things to do . . ."

September 11. The Quinnipiac Council B.S.A. will operate W1GB during the first annual Trader-O-Ree at Camp Sequassen, Winsted, CT. For special QSL, send QSL and SASE to KA1EAJ, Skip Paquette, 121 West Dayton Hill, Wallingford, CT 06492.

September 18-20: The Wright-Patterson AFB MARS, AGA1WP and the Dayton Amateur Radio Association, W3BI will go on the air to commemorate the celebration of the Air Force's 40th anniversary. For further information write Paula DiGennaro, KA8HQJ, 7136 Pineview Drive, Huber Heights, Ohio 45424.

September 19-20: The Wellesley Mass ARS will operate W1TKZ to celebrate the new Novice 10 meter privileges. 1300Z to 0100Z. All Amateurs are welcome especially Novices and Technicians. For a special QSL card send OSL and SASE to Wellesley ARS, 211 Washington St, Wellesley, MA 02181.

September 19: The South Canadian Amateur Radio Society will celebrate its decicentennial by operating special event station W5OU from 1400Z-2400Z. For certificate send QSL and 9x12 SASE with 39 cents postage to SCARS c/o KD5IT, 2735 Poplar Lane, Norman, OK 73072.

September 15-19. The Southern Counties ARA will operate K2BR during the Miss America Pageant, Atlantic City, New Jersey. QSL SASE via SCARA, Box 121, Linwood, NJ 08221.

September 27-28. 1987 Fall Classic and Homebrew Radio Exchange. 2000 UTC Sunday to 0400 UTC Monday. Our object is to restore, operate and enjoy older and/or homebrew equipment of any vintage. CW call "CQ CX"; phone "CQ Classic Exchange".

September 5-6. The Porter County ARC will operate N9RD from 1300Z to 2300Z from the Heston Steam Museum for the annual Steam Show. For further info contact Jurgen, N9RD or Tom, KB8AC, POB 1782, Valparaiseo, IN 46383.

September 26-27: The Council of Eastern Mass. Amateur Radio Clubs (CEMARC) will operate special event stations during the Amateur Radio exhibit at the Museum of Science in Boston, MA. Each station will use the call sign KA1SM.

HAM EXAMS: The MIT UFH Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday September 23, 7 PM, MIT Room 1-150, 77 Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 646-1641. Exam fee $4.25. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

ELMER'S NOTEBOOK

Tom McMullen, W1SL

an introduction to AMTOR

It's digital communications time again, after a brief detour into discussion of the 28- and 220-MHz bands.[1]

July's column covered the basics of RTTY and ASCII, two foundations for more advanced teleprinter communications techniques. This month we'll continue with a look at AMTOR, another aspect of modern digital communications.

In referring to teleprinters, by the way, I'm not limiting the discussion to mechanical devices that print on paper; the term can also apply to electronic systems that "print" their output on a cathode-ray-tube screen (CRT).

QRN here...

One of the problems that has plagued teleprinter communications from the beginning is noise. Oh, sure, noise bothers CW and voice operators too, but that computer most of us have between our ears has a marvelous ability to fill in missing portions of a word or phrase when a static crash or some other noise blots out the signal for a brief period of time. The machinery of teleprinting isn't so smart — it can't infer what was "probably" sent by examining the context of the message. In mechanical systems such as RTTY, a mangled or missing bit of data will result in either a wrong character or no character being printed. In electronic systems using computers or "dumb" terminals,* improper data can still print a wrong character, but if the noise mangled an instruction, the system is likely to "lock up." Often, the only recovery is to shut the equipment off and then turn it on again, which loses any data already received. (And you thought first-contact jitters were bad! Be thankful you're not a computer.)

As all good traffic handlers know, when the message must get through despite poor conditions, a solution to the noise problem is to repeat what's being sent. Accuracy is improved, but throughput (that's a buzzword referring to amount of information transferred per unit of time) is reduced. It's a tradeoff that's acceptable when accuracy is most important.

AMTOR to the rescue

AMTOR is a modern way of doing just that — repeating what is sent. The system was adapted from a commercial scheme devised to improve the reliability of communications with maritime units where garbled text could result in costly delays. The acronym AMTOR comes from AMateur Teleprinting Over Radio.

AMTOR comes in two flavors, Mode A and Mode B. In addition to repeating what's sent, both use a unique code characteristic to allow the receiving station to reject bad data. **Figure 1** shows the letter "Y" in both Baudot and AMTOR codes.

The AMTOR code was developed from the Baudot (or RTTY) code, and there's a direct correlation in most of the characters. The binary representation of "Y" in Baudot is 10101; you'll note that the center five bits of the AMTOR "Y" are also 10101.

Here's where AMTOR gets clever. There's always a ratio of four marks (ones) to three spaces (zeros). This is accomplished by adding ones or zeros to the original five-bit code. If the receiving station finds a character without that ratio, it rejects it as bad data.

In Mode A AMTOR, one station is called a "master," and the other a "slave." The master station is the station that initiates the contact. After contact is established, the master is known as the "information-sending station," or *ISS*. The slave becomes the "information-receiving station," or *IRS*. These roles can be reversed during the contact by either station sending the proper control code to the other. Mode B doesn't use the master/slave concept, but instead repeats the characters being sent in a pattern designed to minimize errors.

---

* A "dumb" terminal is one that can only receive, display, and transmit text; a "smart" terminal contains a microprocessor and circuitry that allows it to also perform complex computing and data-manipulating functions.

Note that packet radio, through computerized error-checking, offers the advantage of noise-free, error-free communication; we'll discuss packet radio in a future column.

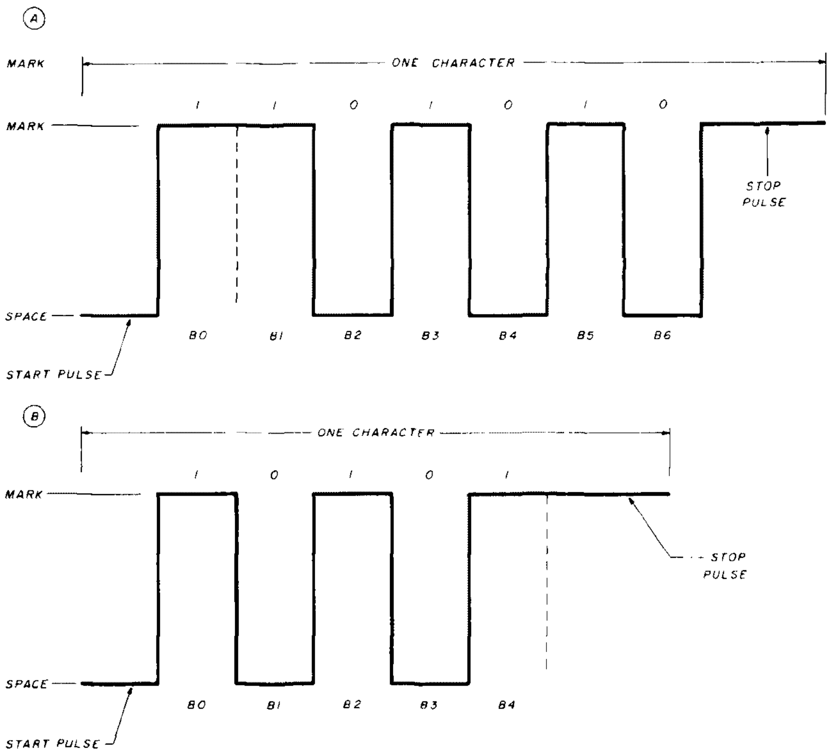


fig. 1. The letter "Y" in AMTOR code at (A), and in Baudot (RTTY) code at (B). The seven-bit AMTOR code was developed from the five-bit Baudot code by adding 1s and 0s to permit checking for accuracy of received bits. Compare these to the ASCII letter "Y" in my July column.

slaving away

In Mode A, the ISS transmits data in groups of three characters, then waits for an acknowledgment. The IRS receives the data and checks it for the constant 4:3 ratio; if the data is good, the receiving station sends an acknowledgment signal in the form of a special control code. The ISS then sends another group of three. If the IRS gets bad data or misses something, it sends a control character that asks for a repeat. Thus, the contact, or QSO, is a series of bursts of data going back and forth.

The transmission rate is usually 100 baud. The transmission of each character requires 70 milliseconds to send, for a group time of 210 msec. The master waits 240 msec for a reply before sending the next group (or repeating the group just sent). This on-and-off operation means that your transmitter will operate with slightly less than 50-percent duty cycle, and shouldn't overheat at reasonable power levels. It also means that your equipment should have fast "turn-around" times in switching from send to receive and back again.

AMTOR equipment has an adjustment to compensate for equipment switching time. If your equipment is too slow, your receiver won't be ready in time to hear the acknowledgment from the IRS; if it's too fast, you'll send the next group before the IRS is ready to copy it. Another type of delay can result from the propagation time between the ISS and the IRS: nearby contacts require less propagation time than those half a world away. AMTOR equipment can also be adjusted to tailor this time for optimum results. (Reliability has its price. There's no free lunch anywhere!)

Obviously, this system is slow. The extra bits, the processing time, and the time spent waiting for an acknowledgment all add up. Even though these times are each only a few milliseconds long, the total lengthens the time required to send information. At 100 baud, however, the speed of data transfer is still faster than most people can type, so the extra bits and wait times aren't too objectionable. A good circuit will transfer data at the rate of approximately 50 wpm. This speed will decrease as conditions get worse, slowing to about 10 wpm as the signal deteriorates, but the system will continue to try for correct copy (talk about dedicated operators!).

There's a catch, though: what if you don't want to use the one-on-one situation where one station is the master and the other is the slave? Perhaps you want to send a message to a network of stations or to one station with others to copy. The first station to acknowledge would be the IRS, and all others would be locked out. Then, too, there must be a mode that allows you to call CQ.

Here's where Mode B comes in. In this system, each character is repeated in a sequence that is calculated to get the information through most accurately. If you know the approximate length of the average noise burst (such as QRN from lightning), and you repeat the characters at intervals slightly longer than that noise-burst length, you have a pretty good chance of getting your message across. That's just what Mode B does.

For example, if I send "antenna here is 3-element beam," but noise wipes out some of it, you might receive "a – en-a h – e is – ele – nt bea-." Your between-the-ears computer can probably deduce what I meant. But if our QSO is being carried out on teleprinter devices, each machine will print what it receives; this can lead to some pretty garbled text because noise bursts can be interpreted as almost anything, even unprintable characters. (No, I'm not talking about a prudish machine that censors the text, but about those control characters that don't print a let-

ter or number, but rather ring a bell, advance the paper, or shift to upper case, for example.)

Now suppose I repeat the message so you can fill in the missing pieces. On the first transmission you receive "a—en-a h—e is—ele—nt bea-." The second time, you receive "-nte-na -ere -s 3 —emen- —am." You can fill in the missing pieces and recover the whole message easily enough, but now the beauty of it all is that your receiving machinery can do the same, and a whole lot faster. Instead of repeating the whole sentence, suppose that I know that the average noise burst is likely to be approximately two to three characters long. If I repeat the text in groups of four, the chances of the message getting through are much greater, and the amount of time spent repeating is kept to a minimum. Again, transmission is at 100 baud, so each character takes 70 msec, for a total of 280 msec for the first transmission; repeat the first four characters, then send the next four and repeat them. The sending sequence for the message above might be:

Ante|ante|nna |nna |here|here| is | is |thre|thre|e el|e el|emen|emen|t bea|t be|am. |am. |

I've inserted the vertical bar (|) to mark off the groups of four characters; it isn't sent as part of the message. Note that spaces between words count as "characters" too; in AMTOR code, each space is indicated as 0011101 (bit 0 first).

In Mode B, the transmitter is on continuously, so it might overheat unless it's designed to handle continuous duty cycle. If this is the case, reduce the power level to something that the transmitter can handle. (Like AMTOR operation, RTTY also requires that most transmitters be operated at reduced power to prevent overheating. Check your equipment instruction manual for duty-cycle information.)

If all this seems complicated and confusing, don't worry — it probably is. The good news is that you don't have to think too much about it; today's equipment has a lot of "smarts" built in. All you need is a teleprinter, a terminal, or a personal computer; add an AMTOR encoder/decoder box, connect it to your transceiver, and watch the lights blink.

Well, maybe it's not quite that easy, but it's not too hard, either. You'll still have to learn how to tune in a station, and what the operating procedures are, but a little careful listening (make that "monitoring") will take care of the latter. For practice in tuning in a station (and learning what one sounds like) tune in W1AW, the Maxim Memorial Station at ARRL headquarters in Newington, Connecticut. The station transmits bulletins on AMTOR Mode B on 14,095 kHz at scheduled times. Novices: remember, you can receive (listen) in Mode B on hf bands other than 10 meters, but you can transmit (reply) in either mode *only between 28.1 and 28.3 MHz.*

Other "listening" spots are 14,075 and 3637.5 kHz. Many stations start there and then move a few kHz up or down to continue QSOs. If you hear a "chirp-chirp" type of operation, it's probably two stations using Mode A. If a signal sounds very much the same as a continuous RTTY signal, it could be either RTTY or Mode B. If you tune it in and the lights on your AMTOR box come on, you're doing something right. Try some schedules on 10 meters and have a ball.

There's more interest in AMTOR in Europe than in the United States, so here's a chance to grab some very interesting DX on a relatively new and fascinating mode of communication.

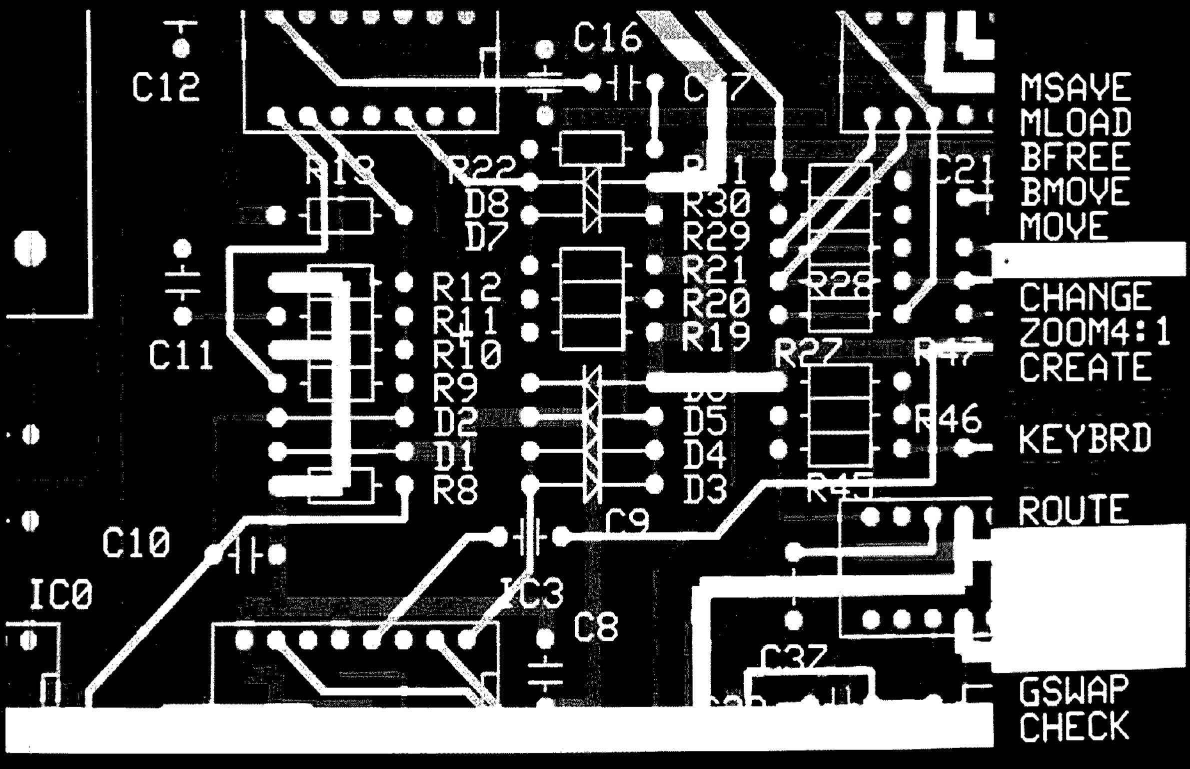
reference

1. Tom McMullen, W1SL, "Elmer's Notebook: An Introduction to Digital Communications," *ham radio*, July, 1987, page 92.

ham radio

OCTOBER 1987 / $2.50

ham radio magazine



professional layout software for amateur radio applications

ham radio

magazine

OCTOBER 1987

volume 20, number 10

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States
one year, $22.95; two years, $38.95; three years, $49.95
Europe (via KLM air mail) $37.00
Canada, Japan, South Africa and other countries (via surface mail),
one year, $31.00; two years, $55.00; three years, $74.00

All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 98

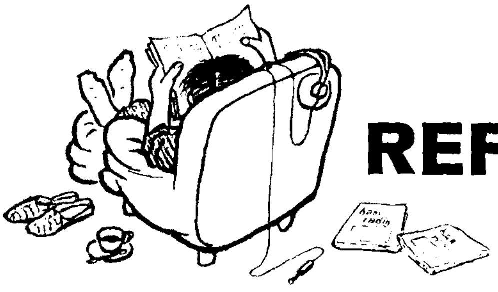
Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second class postage paid
at *Greenville, New Hampshire* 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents



REFLECTIONS

the possessed

During the anything-goes sixties, while attending City College, I shared an apartment with two roommates on the upper west side of Manhattan. This editorial is dedicated to one of them. Without naming names (let's just call him "Mr. A"), this roommate was the antithesis of what most of us Radio Amateurs have become.

We're like magnets. Anything we see that might be remotely useful, even in the far-distant future, will come to us to be saved for that eventuality. Now, I'm not talking about just nuts and bolts. I'm talking real quantity and diversity.

Look around your shack, which in some cases might be considered the entire house. If you're like me, you've probably spread out all over.

What was that sound? The one just before that awful grinding noise and the smell of burning motor? Was it that 1-percent precision, 141.7-ohm resistor you've been looking for since Labor Day — the part you needed to finish your super-deluxe noise bridge — being sucked up into the vacuum cleaner? Well, it's history now. The vacuum cleaner has claimed another victim.

"Just a darn minute!" you exclaim. *"That resistor was carefully placed on the dining room table!"*

Come on. Follow me. Starting from the shack, let's take a quick walk — in our mind's eye — around the house. It's probably impossible, even dangerous, to walk around any other way because of the overcrowding or perhaps because of those three 6-foot racks of tube equipment you've built over the years. All those dangling jumper cables (control, audio, digital, and rf) seem to want to reach out and trip people. Come on, don't let me hear that argument you give your spouse about how keeping all that equipment going helps keep the house warm, thereby cutting the the fuel bill, and hasn't she noticed how nice and dry it is down in the basement when all those pretty tubes are lit? I've heard all those justifications before. In fact, I've used some of them myself.

As painful as it may be, let's leave the shack and move on. No point stopping at the kitchen or dining room tables; we all know what we'll find there.

If you're at all like me, you have many different interests and probably subscribe to a number of magazines that address those interests. Are the magazines all neatly stacked on a bookshelf in the radio room — just as pictured in any of the operating manuals that show what the typical ham station looks like? Naah. Who are you kidding? Those magazines are strewn all over the place — scattered atop the TV and on side tables and even chairs, heaped in piles in corners, in the attic, in the hallway, the bathroom, the garage, and, of course, on the floor. Did you ever consider the possibility that your spouse might consider this an encroachment on *her* living space?

Speaking of the garage, that's a story in itself. It's amazing to consider how seven sections of Rohn 45 can fit in there so nicely. But the XYL's car? Well, that's a different matter. Maybe winter won't be so bad after all.

I won't even mention those drums of surplus wire, cable, or whatnot that you picked up at that flea market in 1979. What a deal! Heck, you're going to help her shovel the snow off the car this winter anyway, right?

Moving outside, did you know that the great outdoors offers almost unlimited storage capability? Of course you do. Why, there's the evidence: more rusting tower sections, some sturdy anchors, a hundred feet of guy line, and a 6-foot dish! Too good to sell, give away, or discard, they're also too big for the garage. But they're not too big for the great outdoors!

"All right!," you protest. *"Maybe there's some truth to what you've been saying. But what's the point?"*

This is it: perhaps October's the time to take another look at what we possess, or more appropriately, what possesses us. Maybe this is the time to go through the entire house, gather all our treasures together, and decide what's really important, what we *really* want to keep. Let's sell the rest, or better yet, donate it to a worthy cause like that Novice down the block. After all, we've gotta start 'em right on this acquisition madness, don't we?

I hope you appreciate the gravity of the chance I'm taking by writing this editorial. If my XYL ever reads this, I might have to practice what I preach. As a friend of mine is wont to say: *"End of message."*

And what about the legendary Mr. A, to whom this editorial is dedicated? Well, Mr. A owned exactly two shirts and two pairs of shoes, pants, and socks — and barely anything else. When the time came to move, I had to rent a trailer to cart my possessions. Mr. A put everything he owned into his attache case and walked away.

Rich Rosen, K2RR
Editor-in-Chief

comments

ground plane antennas

Dear HR:

I was rather taken aback at a recent ham club meeting when a couple of friends informed me that according to a letter to the editor in *ham radio*, my "offset drooper" ("The Offset Drooper: An Improved Ground Plane," January, 1986, page 43), had been invented years ago by a Frenchman.

DJ0TR/OE8AK's letter in the June, 1987 issue, in which he discusses the origins of the venerable ground plane antenna, states, immediately following his reference to my article, "This VHF/UHF antenna was invented several years before in France . . . ."

A careful reading of the letter, however, makes it quite clear from the context that the statement "This VHF/UHF antenna was invented several years before . . ." applies to the earlier mentioned classic ground plane credited to Dr. George Brown. But apparently, if one hurriedly skims the letter, the remark can be mistakenly applied to the "offset drooper" version of the ground plane antenna.

While on the subject of originality, I'm surprised that the matter of French prior art pertaining to ground plane type antennas has taken 50 years to surface. I do know that I certainly am not in a position to pass judgement as to worldwide prior art. My information was taken from the article, "The Ground Plane Antenna: Its History and Development," by Harold Vance, Sr., W2FF (now deceased), which appeared in the January, 1977 issue of *ham radio*.

George Brown and Harold Vance were both highly respected VIPs at RCA during World War II. As section head and project officer on some new USMC electronic equipment under development, I used to visit Harold Vance and his crew of key engineers at the RCA Camden plant frequently. He was a fine gentleman, with exceptional electronics savvy and management know-how. I regret I didn't get a chance to meet George Brown, who, I believe, was at RCA Labs (elsewhere) at the time.

In hindsight, my offset drooper article could have been more accurately titled "An Improved Drooping Ground Plane." For over three decades, drooping radials have been widely used by the ham fraternity to permit direct connection of 50-ohm coax. However, this aggravates antenna effect. The Offset Drooper configuration provides a substantial reduction in antenna effect without adding a detuning sleeve or an extra set of radials, while still maintaining a 50-ohm match.

Woody Smith, W6BCX
Anaheim, California 92804

is nothing sacred?

Dear HR:

With this rather untimely heading ["Is Nothing Sacred?" — Ed.], The New York Times recently reported slight changes in more than 100 of the fundamental constants used in science. These changes represent a consensus of scientific opinion by the world's leading measurements laboratories, including those in the Soviet bloc and our National Bureau of Standards as well.

It is gratifying to learn that the speed of light hasn't changed, and remains at 299,792,458 meters per second. I shall leave it to some computer whiz to translate that into feet and inches; my hand calculator is inadequate.

However, whereas this number was previously termed "approximate," it is now defined as "exact," and the second is considered constant. The meter is then defined in terms of the velcity of light and the second — a nice Catch-22! Greater accuracy will be achieved with future improvements in measurement.

The meter, as originally proposed by a French vicar in 1670, was defined as 1 ten-millionth of the distance between the equator and the North Pole. It was subsequently translated into two scratches on a platinum bar kept at 23 degreees C. (Now that we deal in subatomic distances, this is gross measurement indeed.) Thus the scientists have defined the meter as the distance that light will travel in 1/299,792,458 second!

Obviously, you won't have to throw away your tape measure when you put up that new beam!

Josef Darmento, W4SXK
Merritt Island, Florida 32952

bird chaser

Dear HR:

Noticed the letter from Bernard Kirschner in the May issue ("Comments," page 6).

He's having troubles using an owl as a bird chaser, is he? Perhaps he should use one of those inflatable snakes from the local garden shop instead. Tie one end of it about halfway out along the boom and the other end on the pole so it looks like it's just climbing onto the boom. Those things would scare me off — as well as all manner of feathered creatures.

Charles Chrestien
Sunnyvale, California 94086

neighborly gesture

Dear HR:

There's a very useful technique for dealing with neighbors who complain of TVI. Instead of making critical comments about their television receivers, try lending them a table model color receiver fitted with the proper filters. Then ask them to help you perform a simple test.

Three or four days later they'll ask you to tell them how they can fix *their* receivers. Amazingly, even the most formerly rabid neighbor will approach you in a very friendly and reasonable frame of mind.

As proof of the effectiveness of this method, how many Amateurs do you know who have ground radial systems covering not only their yards, but a side neighbor's yard and the yard of the neighbor in the back as well?

John Labaj, W2YW
Elsmere, New York 12054

low-cost pc board layout software

The price *has* dropped — but watch out for those options!

The price of sophisticated printed circuit board layout packages has plummeted. For less than $1000 – often *much* less – you can buy an easy-to-use package that can handle almost any board layout. Even if you've never used computer-aided design (CAD), you can master any of these packages quickly.

Until recently, pc board designers had to choose between sending their designs to pc board service bureaus or using expensive layout packages that ran on dedicated work stations. CAD packages priced at less than $1000 were drafting tools at best. But all that's changed; today's relatively low-cost pc board layout software packages provide almost the same features as work station-based systems. What's more, they run on personal computers, which means they're now within reach of clubs and individual Amateurs.

All packages aren't equally suited for all applications, however. For analog designs, a package should provide an area-fill capability, which you'll need for constructing irregularly shaped ground planes. Some packages are tailored for digital designs and consequently don't provide a way to create copper planes of arbitrary shape.

Most of the low-cost packages, however, offer tools for filling in copper areas. For example, area fill is a standard feature of Accel Technologies' *Tango-PCB*® program for IBM PCs and compatible personal computers. Together with the package's 1-mil grid, the area-fill command enables you to create copper areas and thick tracks for microstrips and ground planes. Its $495 price includes software, documentation, a function key overlay, a sample pc board, and a 30-day money-back guarantee.

Procad xtra®, from Interactive CAD Systems, features filled areas for ground planes and lets you select up to seven fill patterns and styles of lines. Complex symbols such as standard power-supply layouts or memory bus structures can be stored in the program's library for repeated use. Procad xtra costs $695; it runs on IBM PCs and on Digital Equipment Corporation's VAX minicomputers.

Similar features are found in QTech's *Qwik Tek*® package. That's not too surprising – they were developed by the same programmers. Like Procad xtra, Qwik Tek runs on IBM PCs and on DEC VAXs; the base price of Qwik Tek is $695.

automatic layout software

Qwik Tek and Procad xtra aren't alike in all respects. Procad xtra is a purely interactive system, which is all you'll need for most analog applications. But for designs with large numbers of components, you'd need a program that could position them on a layout and draw interconnections among them. A $7900 version of Qwik Tek includes these capabilities, offering a schematic editor, interactive layout, automatic placement, and an autorouter.

An autorouter interconnects the components on a layout automatically. The sophistication of the autorouters in low-cost pc board layout packages approaches that of autorouters in the most advanced work stations and mainframe-based layout systems. Yet the price of an IBM PC-based autorouter can be relatively low. For $750, CAD Software's *Pads-Route*® autorouter provides three routers: power-and-ground, memory, and maze. The power-and-ground and memory routers specialize in power supply and RAM interconnections; the maze router interconnects all other digital and analog components.

By Eva Freeman, 108 Trapelo Road, Lincoln, Massachusetts 01773

Table 1. Low-cost pc board layout packages.

Company	Product	Base price	Required hardware	Operating system	Auto-router	Auto-router price	Auto-placement	Compatible net lists	Max. no. of colors	Max. no. of traces	Max. no. of components	Max no. of layers
Abacus Software Box 7219 Grand Rapids, MI 49510 (616) 241-5510	PC Board Designer	$195	Atari 520ST or 1040ST	Gem	X				2	1100 lines	250	2
Accel Technologies Inc. 7358 Trade St. San Diego, CA 92121 (619) 695-2000	Tango-PCB	$495	IBM PC or compatible	MS-DOS	X			Accel; Omation; Orcad	16	26,000 lines	1000	9
Advanced Microcomputer Sys. 2780 SW 14th St. Pompano Beach, FL 33069 (305) 975-9515	PC-PRO	$250	IBM PC or compatible	MS-DOS	X	$250		AMS FutureNet Racal-Redac	16			256
B & C Microsystems 355 West Olive Sunnyvale, CA 94086 (408) 730-5511	PCB/DE	$395	IBM PC or compatible	MS-DOS and AutoCAD				B & C Microsystems	16			
CAD Software Inc. Box 1142 Littleton, MA 01460 (617) 486-9521	Pads-PCB	$975	IBM PC or compatible	MS-DOS	X	$750	X	FutureNet	16	4511 nets	764	30
Dasoft Design Systems 1827B Fifth St. Berkeley, CA 94710 (415) 486-0822	Project: PCB	$950	IBM PC or compatible	MS-DOS	X			Dasoft	6			4
Design Computation Inc. 10 Frederick Ave. Neptune, NJ 07753 (201) 922-4111	Draftsman-EE	$749	IBM PC or compatible	MS-DOS	X	$2450	X		16	4000 nets	300	20
Douglas Electronics 718 Marina Blvd. San Leandro, CA 94577 (415) 483-8770	Douglas CAD/CAM	$95	Apple Macintosh	Macintosh					2			
Interactive CAD Systems 2352 Rambo Court Santa Clara, CA 95050 (408) 970-0852	Procad Xtra	$695	IBM PC or compatible	MS-DOS				ICS	16	2000 nets		50
QTech Inc. 256 E. Hamilton Ave. Campbell, CA 95008 (408) 370-3910	Qwik Tek	$695	IBM PC or compatible	MS-DOS	X	$7205	X	QTech	16	1500 nets		50
Softcircuits Inc. 401 SW 75th Terrace North Lauderdale, FL 33068 (305) 721-2707	PCLO	$500	Commodore Amiga 1000	Amigados	X				16			
Vamp Inc 6753 Selma Ave. Los Angeles, CA 90028 (213) 466-5533	McCAD	$395	Apple Macintosh	Macintosh	X	$995	X	Vamp	2	32,000 lines	32,000	6
Visionics Corp. 1284 Geneva Dr. Sunnyvale, CA 94089 (408) 745-1551	EE Designer	$975	IBM PC or compatible	MS DOS	X	$975	X		16		999	26
Wintek Corp. 1801 South St. Lafayette, IN 47904 (317) 742-8428	Smartwork	$895	IBM PC or compatible	MS-DOS	X			Wintek	3			6

It's not reasonable to expect too much of pc board autorouters priced at under $1000. They can't match the speed of mainframe or work station-based autorouters, nor can they consistently route all boards to completion, as can some mainframe or work station-based autorouters.

Though these packages are certainly more than adequate for typical Amateur projects, you shouldn't expect, for example, to use a PC-based package to design an eight-layer, 500-IC board. Although several of the PC-based layout programs listed in **table 1** do permit eight layers and 500 components, their autorouters just can't route boards of such complexity. If you do find your designs limited, they'll be limited not by the maximum number of components or layers, but instead by the maximum number of traces your software package will allow.

Table 1 lists the maximum number of traces each package can handle. Note that vendors differ in the way they specify this capability. Some specify a maximum number of nets; others, a maximum number of lines. A net links all pins that are to be connected to-

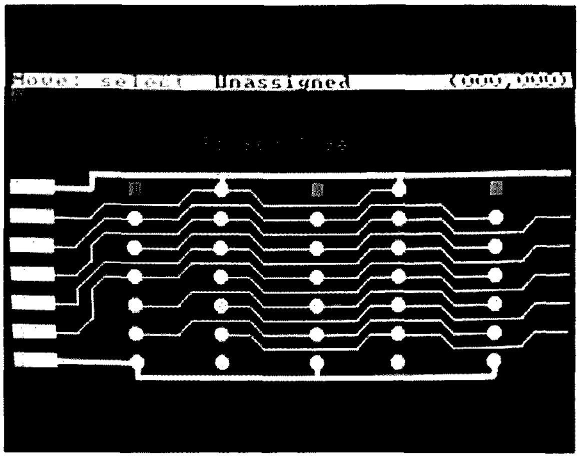


fig. 1. *PC Pro*, a $250 pc-board layout program from Advanced Microcomputer Systems, accepts schematic designs from either the package's own schematic editor or from Future-Net's IBM PC-based schematic-capture program.

gether; a line simply connects two points. A line doesn't even necessarily connect two components; if a connection includes a 90-degree bend, some vendors consider the connection to be two lines. A typical design contains roughly five lines per net. Thus, it's safe to assume that a package that specifies a 2000-net maximum is equivalent to one that specs a 10,000-line maximum.

Caution: the specifications provided in **table 1** can be misleading. Although a package might permit 1000 nets, 300 components, and 50 layers, it's best to stay away from the specified limits, because as a design approaches the limits of a package, the software starts to run more slowly and the autorouter generally fails to complete all the interconnections.

Any limitations of the low-cost packages are largely attributable to the limitations of the computers on which they run. The MS-DOS operating system used by the IBM PC, for example, can address only 640K of memory. Thus low-cost packages that run on IBM PCs and compatible personal computers can't handle databases of greater size.

Those working in especially demanding applications can add an extended-memory board to overcome this limitation. Although most PC-based layout packages can't yet take advantage of extended memory, CAD Software's programs can: their $250 Pads-Large-SW option increases the maximum number of components from 539 to 764, and increases the number of connections from 2711 to 4511. This package is the first to use extended memory, but you'll soon be seeing other layout programs that use it.

It's possible to accelerate IBM PC-based layout packages by running them on 80286 or 80386-based personal computers. Most vendors of PC-based layout packages have written their software to run on most compatible PCs (see **table 1** for details).

Whether routed manually or automatically, a layout can be only as good as component placement permits. If you don't optimize the placement of components on your board, your board will have more "vias" (plated-through holes) and longer interconnections than should be necessary. In many cases, the autorouter will simply fail to route the board completely. In all cases, pc board fabrication costs will be higher and system speed will be lower than they might be.

Even if you don't use an autorouter, you'll find that pc board layout packages can assist you in interconnecting components. Most of the packages include a rat's-nest utility that displays straight-line connections between components. With it, you can shift components on your layout to minimize the length of interconnections.

the bottom line: price, practicality

For Amateurs, the most important feature of a pc board layout system is likely to be its price. The least expensive package available for the IBM PC is Advanced Microcomputer Systems' $250 *PC PRO*™ (**fig. 1**). This program gives users extensive control over designs; for example, it offers trace widths from 0.001 to 0.255 inches, and a single net can include a combination of trace widths. Similarly flexible, the symbol library includes footprints for standard ICs, connectors, and discrete components — and offers tools for creating new pad shapes.

Some of the less expensive packages were designed for computers other than the IBM PC. **Table 1** lists four such programs. The $195 *PCBoard Designer*™ from Abacus Software (**fig. 2**) provides pc board layout tools for Atari users. The package offers component rotation in 90-degree increments and a choice of 45- or 90-degree routing paths; output is configured for Epson dot-matrix printers.

Softcircuits' $500 *PCLO*™ package for the Commodore Amiga provides pan capabilities and fast screen redraws to keep the overall layout coherent while you're working. Ten work-area memories provide instant movement among disjoint areas.

Apple Macintosh users can choose between two programs: Vamp's *McCAD*® and Douglas Electronics' *Douglas CAD/CAM*.™ The graphics-manipulation capabilities of the Macintosh are particularly attractive for analog applications; the line-and-pad-array generators in McCAD, for example, cut down on the time you need to create ground planes.

You can buy a Douglas CAD/CAM for as little as $95, but it won't provide automatic layout features or schematic capture. The basic package doesn't include interfaces to pen plotters or photoplotters; you have to send your layout to Douglas and have them fabri-

cate your pc board* — or make it yourself from the image you see on the screen. You can buy a pen-plotting option or a combined pen-plotting and photo-plotting option, but they'll cost you $300 and $500, respectively.

Although the least expensive package runs on the Macintosh, most low-cost layout programs were designed to run on the IBM PC. One vendor, B&C Microsystems, has held down the cost of its IBM PC-based *PCB/DE®* program by linking the software to Autodesk's *AutoCAD®* drafting package. Strictly speaking, the total package costs more than $1000 because you must purchase AutoCAD; but if you already own AutoCAD, you'll find that the $395 program provides more features than comparable packages that include drafting software.

Most PC-based packages don't require AutoCAD or any other additional drafting software; it's included with the pc board software. Wintek's $895 *Smartwork®* program, for example, includes all the graphics tools you need for pc board layouts. Though the program doesn't have an autorouter, it does offer an interactive router that finds the best possible connection between each successive pair of interconnections. Besides its layout package, the company offers an $895 schematic-capture program and is introducing an automatic router.

Visionics has recently added a $975 automatic router to its $975 *EE.Designer®* pc board layout package (fig. 3). The autorouter can route not only two-layer boards but surface-mount devices and multilayer boards as well.

what options do you need?

Each one of these low-cost pc board layout packages comes with a "catch." The least expensive product that most vendors sell is the basic program; the optional programs and hardware dramatically increase the total cost. Like automobile manufacturers, vendors of low-cost pc board layout software often derive their profits not from the basic package, but from the options that accompany it.

Unfortunately, these "optional" programs aren't always optional. For example, Design Computation's basic *Draftsman-EE®* provides only a graphics editor, a component library, and bill of materials and parts list utilities. To generate a rat's nest display and to check for design rule violations, you'll have to purchase the optional *DC/Check®* program. An autorouter is yet another option. Often, these options are necessary.

Draftsman-EE is priced at $749, DC/Check costs $398, and the autorouter lists for $2450. For about $4000 you can purchase all of these tools, as well as

*Estimated price for 3 1/2 × 4 1/2 inch board, 250 holes, no gold: $193 for setup, $7.80 per board in small quantities. Price decreases for larger quantities.

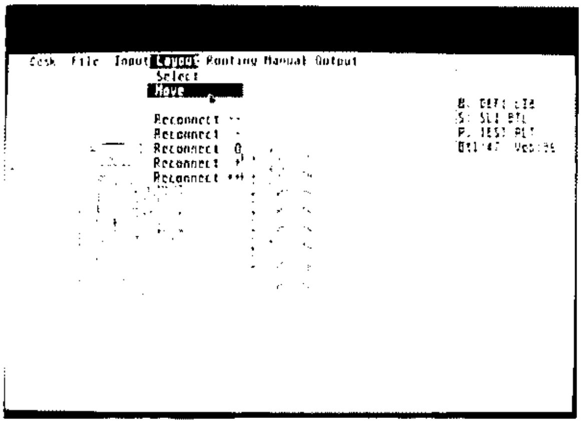


fig. 2. This rat's nest display shows direct connections among all components. Using the rat's nest display in Abacus Software's *PCBoard Designer*, you can interactively complete any one- or two-sided pc board.

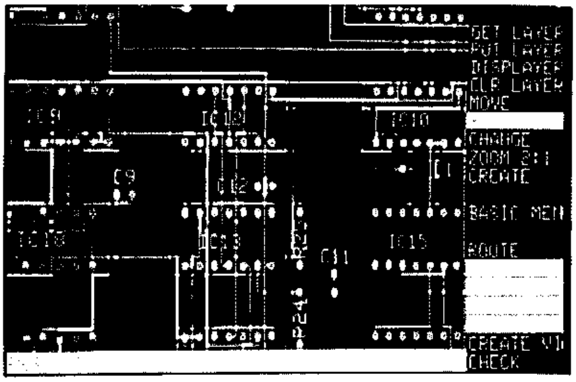


fig. 3. Even inexpensive packages can handle mixed analog and digital designs. *EE Designer*, from Visionics, routed an 88-component analog/digital board with 269 interconnections to 100-percent completion in six minutes.

12 months of telephone assistance; while it's a modest price for a complete professional pc board layout system, it's still more than five times the cost of the basic program alone — and far more than most Amateurs would probably be willing to spend.

Even though these options, especially for packages that list for less than $1000, greatly increase the cost of pc board software, the total cost — in professional applications — is still far less than the cost of using pc board service bureaus or work station-based layout systems. In considering the purchase of pc board layout software for Amateur applications, then, it's probably best to keep in mind the advice of the United States Postal Service: "If an offer sounds too good to be true, it probably is."

reference

1. Eva Freeman, "Low-cost pc board layout software," *EDN*, March 18, 1987, page 138.

ham radio

antenna relay sequencing

Use one basic protection circuit for normal switching or full break-in

Antenna relays are very expensive, and while bargains can sometimes be found on the surplus market and at swap meets, it takes time to find them.

Running 1500 watts into 50-ohm coax means that more than 5 amperes of rf current flows at almost 300 volts. Coax relays, with their contacts and spacing kept relatively small to preserve the impedance match, are definitely not designed to hot-switch this kind of rf power. If you try using them for this, you'll burn out the contacts; in fact, Murphy's Law ensures that transmit contacts will burn out completely just as you hear the rare DX country or VHF grid square you've been looking for.

Another form of antenna relay failure that's as common as burning out the contacts is arcing from the transmitter connector to the relay shell. This is caused by abnormally high rf voltage output from a high-power amplifier under open-circuit conditions.

A power amplifier also needs protection from any open-circuit condition, even for just a fraction of a millisecond. If a tube-type amplifier sees an open load at any time, either at the beginning or the end of a transmission, plate circuit arcing and damage to the components may occur. In solid-state amplifiers, an open load can destroy the transistors instantly.

The need for sequencing a mast-mounted VHF preamplifier is well known. GaAsFETs certainly aren't designed to handle several hundred watts, even for the few milliseconds it takes for a relay to switch.

This article discusses the most common case of a power amplifier and an ordinary coaxial antenna relay. The same basic circuit is used for full break-in with vacuum relays; in such a situation, the delay periods will simply be shorter. The same circuit can also be used to sequence mast-mounted VHF preamplifiers, together with an interface circuit to delay the exciter.

design criteria

To protect the relay and amplifier when the push-to-talk (PTT) line is closed, the amplifier turn-on should be delayed long enough for the relay contacts to close — and, most important, to have settled down after bouncing. To protect the relay and amplifier when the PTT line is opened, the relay contacts should be held in long enough for the amplifier output to have dropped to zero.

Each unit should, as much as possible, "take care of itself." This means, for example, that the relay should not depend upon a certain capacitor in the exciter or amplifier for a delay. Because you might want to use a different exciter or amplifier later on, the sequencing circuit should be treated as an integral part of the antenna switching mechanism.

circuit specifications

The timing functions of amplifier hold-off at the beginning of a transmission and relay hold-in at the end of a transmission are separated, greatly simplifying the selection of timing capacitors.

The control line for the circuit conforms to the following standards, which I've adopted for all the equipment in my shack: the open-circuit voltage on the control line is negative, and does not exceed −1 volt; the closed-circuit current on the control line does not exceed 1 mA; and the control line is diode-isolated. The first two standards ensure that the control line may be easily controlled by other such circuits, using inexpensive, easily obtainable, low-voltage PNP transistors, without the need for complicated interface circuits or relays. The result is that everything in the shack (except the antenna and other rf circuits) is controlled by solid-state switching. The final standard al-

By Mark Mandelkern, KN5S, 5259 Singer Road, Las Cruces, New Mexico 88005

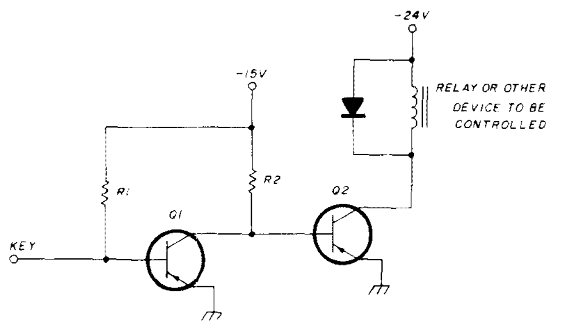


fig. 1. Basic two-transistor PNP switch.

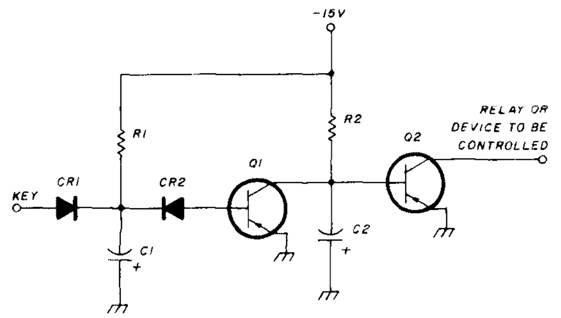


fig. 2. Basic switch with diode isolation and timing capacitors added.

lows the control lines of any number of such relay circuits, power amplifiers, drivers, transverters, preamplifiers, or other items to be tied in parallel, with no interaction. If the exciter's PTT line conforms to these standards, or is fitted with an appropriate interface circuit so that it does conform, it may be tied in parallel with the control lines of any number of other pieces of equipment, along with the PTT switch on the mike stand and the foot switch. A master band switch on the operating bench allows you to select which amplifiers, transverters, or antennas are to be tied in at the same time.

Since my exciter has a negative voltage on the PTT line, and my tetrode amplifiers use negative bias standby switching, I've used negative relay supplies and PNP switches for everything in the shack. However, this circuit can also be used with positive supplies by merely substituting NPN transistors and flipping over all the electrolytic capacitors.

A basic two-transistor PNP switch is illustrated in **fig. 1**. I use dozens of these switches in my shack. Most of the transistors are available for about ten cents. The relay drivers (which must handle high current) and the tetrode amplifier bias switches (which must handle high voltage) cost a bit more. I've used this circuit to convert all the gear I've built with relays over the last 40 years to solid-state switching; none has ever failed.

circuit description

The switching operation shown in **fig. 1** is very simple. Were it not for Q1, resistor R2 would supply enough base current to saturate Q2. This lowers the collector voltage to a very low value, which energizes the relay and enables the amplifier or other circuits. In the unkeyed state, resistor R1 supplies enough base current to saturate Q1, lowering the voltage at the collector of Q1 to about −0.1 volts, much lower than the −0.6 volts needed at the base of Q2 to turn it on. Thus, in the normal state, Q1 is on and Q2 is off. Now what happens when the key is closed?* Keying the circuit grounds the base of Q1, turning it off. This removes the grounding (by the collector of Q1) from the base of Q2, allowing R2 to turn it on. Now the collector of Q2 drops to about −0.1 volts, enabling the relay or other device. Having the top of the relay coil always hot is one clue to the simplicity of this circuit. The transistors all have their emitters grounded and are either on or off, so their collectors either present a ground to the next stage or do not. Everything in the shack is enabled by simply grounding a terminal. There's no need for making two-wire connections when you want to apply a voltage to something.

The basic circuit shown in **fig. 1** needs only diode isolation and timing to become a full working device. These features have been added in **fig. 2**.

diodes provide isolation

Diode isolation is provided by inserting CR1 in the key line. If two or more of these switches have their key lines all tied together, the diodes CR1 in each switch will prevent any current flow between switching circuits. There's only one problem: with CR1 in the key line, closing the key reduces the voltage at the low end of R1 only to the forward voltage drop of the diode, which is just about the same as the −0.6 volts required to turn on the base-emitter junction of Q1. Thus, Q1 may or may not turn off, depending on the characteristics of the diodes and transistors, the temperature, and other such details. Diode CR2 saves the day by producing a 0.6-volt drop between the low end of R1 and the base of Q1. Now the voltage at the low end of R1 must be about −1.2 volts to turn on Q1. Closing the key drops it to −0.6 volts, and Q1 goes off with absolute certainty. Thus CR2 fixes the problem caused by the isolating diode, CR1.

*"Key" is a generic term used here for the point in any solid-state switch, relay circuit, exciter, or amplifier which is grounded in order to enable the device. Only in a CW keying circuit would "key" indicate a real telegraph key, and even then we'd usually be referring to the output of an electronic keyer. In this antenna relay sequencing circuit, the PTT line connects to the "key" terminal of the switch.

Figure 2 shows the general form of the switch, with two timing capacitors, although we use only one capacitor in each of the separate antenna relay and amplifier switching circuits. (Both capacitors could be used in certain applications, when both turn-on and turn-off delays are desired.) Capacitor C2 provides a turn-on delay (which we will use for the amplifier), while capacitor C1 provides a turn-off delay (which we will use for the relay). When the key is closed, C1 discharges immediately through CR1, and Q1 turns off. This allows R2 to turn on Q2, but not instantaneously. It must charge C2 up to about −0.6 volts, and this takes a bit of time. Thus C2 provides a turn-on delay, but C1 doesn't affect the turn-on. Now when the key is let up, this allows R1 to turn on Q1 — but, again, not instantaneously. It must charge C1 up to about −1.2 volts, and this provides the turn-off delay. As soon as Q1 turns on, its collector discharges C2 immediately, so C2 doesn't affect the turn-off time.

separate relay and amplifier switching

It's the clean separation of functions between C1 and C2 that makes the use of two separate switching circuits — for relay and amplifier — well worth the few extra parts. In the relay switching circuit, there's no C2 and the turn-off delay capacitor C1 doesn't delay the turn-on. In the amplifier switch, there's no C1 and the turn-on delay capacitor C2 doesn't delay the turn-off. Although there may be circuits that will do all this with one transistor, the adjustment of turn-on and turn-off times is much more complicated, there's no isolation (so key lines can't be tied together), and hot two-wire connections are often required. The sequencing could also be done with timer ICs, but this circuit seems simpler and may be less susceptible to rf pickup problems. Instead of comparators and timer thresholds, this circuit simply uses the base-emitter junctions of the transistors, which have sharp thresholds at about 0.6 volts with hard turn-on currents, resulting in a very sharp positive action. Timer IC circuits would still need the timing capacitors, transistors for relay drivers, and transistors or relays in interface circuits to match PTT lines and amplifier control lines.

selection of bias resistors

The basic switching circuit shown in **fig. 1** doesn't show the values of the bias resistors R1 and R2. These depend on the load current to be switched. Take first an antenna relay switch. A typical 24-Vdc antenna relay draws about 80 mA — let's say no more than 100 mA. We don't need the exact relay coil current, but rather just an upper limit for design purposes; our circuit will work well with any relay drawing less than this limit. To ensure that Q2 turns on hard at this collector current, a good rule of thumb is to provide a base current of about 10 percent of the collector current. This is like asking the transistor to have a gain of 10; the transistors we'll be using have typical gains in the 50 to 200 range, so this is quite a conservative rule. For Q2 to turn on hard means that with the 100-mA collector current, the collector voltage should drop quite low, to about 0.1 or 0.2 volts. This is not to ensure that the relay coil will get the full 24 volts (it will probably work fine at only 20 volts), but instead to keep the Q2 collector dissipation low. At 0.2 volts this will be only 0.02 watts, but if Q2 doesn't turn on hard, and the collector voltage drops only to 4 volts, the dissipation will be 0.4 watts, more than the rating of a typical ten-cent transistor. So for a 100-mA collector current, we'll provide a base current of 10 mA. The bias resistor R2 should then have the value $R = E/I = 15/0.01 = 1500$ ohms. The power in R2 will be $P = I^2R = (0.01)^2 \cdot 1500 = 0.15$ watts, so a 1/2-watt resistor will be satisfactory.

Q1 has to sink the 10-mA current in R2 in order to keep Q2 off until we push the PTT button. The collector voltage of Q1 should be as low as 0.1 to 0.2 volts, well below the 0.6 volts required by the base of Q2, so that Q2 will stay off. We apply the same rule of thumb as before; Q1 needs only 1-mA base current in order to sink 10 mA in the collector circuit. Thus for R1 we need a value of $R = 15/0.001 = 15$ k. Of course, the voltage across R1 isn't the full 15 volts, because of the small voltage drop in CR1 and the base-emitter junction of Q1. But there's no need here for mathematical precision. The power in R1 will be only 0.015 watts, so we'll use a 1/4-watt resistor. (Whenever the required current comes out less than 1 mA, I always provide 1 mA anyway; this avoids unusually low currents, thereby lessening any possibility of problems from leakage in the PTT line or rf pickup, and ensures that the output transistor in any switch, even if built to switch only another 1-mA line, will sink at least 10 mA, and will thus switch several 1-mA lines simultaneously if necessary.)

The current gain of the two transistors together is the product of the individual gains. Thus, to be safe, we assume a combined gain of 100, although 10,000 would be a more typical value. It's this gain of at least 100 that allows the 100 mA relay coil to be controlled with only 1 mA on the PTT line.

The amplifier switch bias resistors are even easier to select. If the amplifier bias switching circuit follows the standards listed above, you'll need to sink only 1 mA on the amplifier control line. So 15-k, 1/4-watt resistors will be acceptable for both R1 and R2. We'll leave the bias switching problem to the amplifier itself. This will keep the bias, up to −300 volts, off our control lines and out of our station band switch. The bias switch will be discussed below.

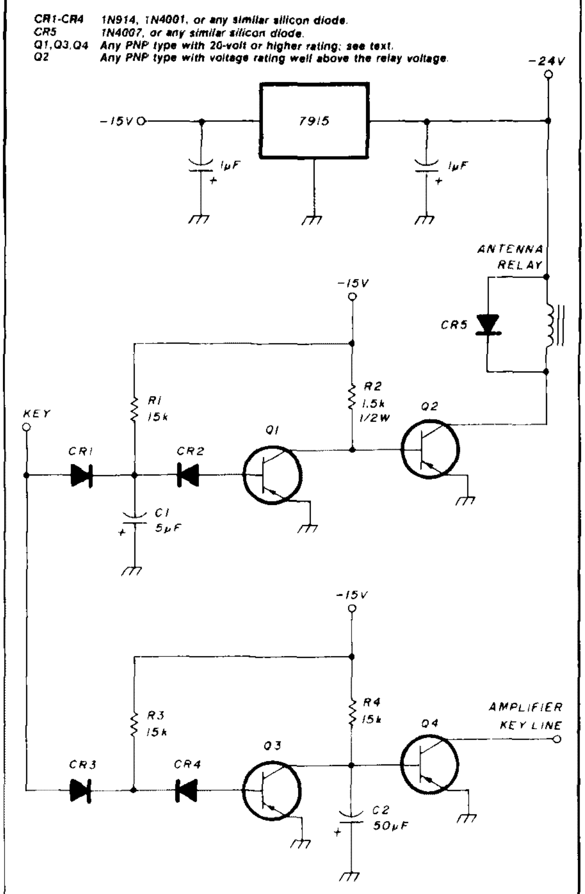


fig. 3. Complete sequencing circuits. Component values shown are for a typical 24-volt antenna relay; for other relays, see text. Not shown is rf filtering on all lines that lead outside the box, and disc ceramic bypass capacitors from base to emitter of each transistor. This filtering with rf chokes and bypass capacitors follows standard practice; actual values of the components will depend upon the frequency of operation.

selecting the timing capacitors

Figure 3 shows a typical complete sequencing circuit — in this case, for a 24-volt relay. The −24 volt relay supply is further dropped to −15 volts for the timing circuits. Since the voltage used affects the timing, this ensures that if the relay is changed to one with a different coil voltage, the timing circuits need not be readjusted.

Because of variations in the actuating time of different relays, it won't be sufficient to merely provide component values; the method of calculation must be explained. The time constant formula T = RC is usually used to choose circuit values in an R-C timing circuit, as in **fig. 4**. The units are seconds, ohms, and farads, but if kilohms and microfarads are used for R and C, the formula conveniently gives the time, T, in milliseconds (ms). The time constant, T, is the time required to charge the capacitor to about 63 percent of the applied voltage, V. In the circuit used here, however, the capacitors never charge beyond about −0.6 or −1.2 volts. To find the exact time to reach this voltage requires a complicated exponential-growth formula. But in this situation the level of charge is less than 10 percent of the applied voltage, so a much simpler formula will suffice:

$$v \approx \frac{t}{T} V \qquad (1)$$

This is a straight-line approximation to the exact voltage. Here, *V* is the applied voltage, *v* is the voltage reached after time *t*, and *T* is the time constant. The formula indicates a simple proportionality between the time and the voltage. Thus, in a circuit with a time constant, T = 500 ms, and an applied voltage of V = 15 volts, the capacitor will charge to about v = −0.6 volts (4 percent of the applied voltage) in about t = 20 ms (4 percent of the time constant). For a 10-ms antenna relay, this delay would be enough to hold off the amplifier while the relay closes.

Once we have the required time constant, it's easy to find the value of the capacitor needed in each bias circuit. With a 20-ms relay, we may wish to delay the amplifier for 30 ms, in order to allow for contact bounce. Using the relationship

$$t \approx \frac{v}{V} T \qquad (3)$$

with the values v = 0.6 volts and V = 15 volts, we find we need a time constant of

$$T \approx \frac{15}{0.6} \cdot 30 = 750 \; ms \qquad (3)$$

The delay capacitor C2 is on the base of Q4. If the switching circuit in the amplifier follows the standards

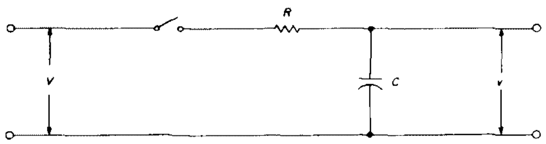


fig. 4. RC timing circuit. The time constant of this circuit is defined by T = RC, which is the time required for the voltage v on capacitor C to reach about 63 percent of the applied voltage V. The exact time required for the voltage on capacitor C to reach a specified voltage v is given by t = −T ln (1 − v/V). However, it is not necessary to use such a precise formula. The approximate time required for the voltage on capacitor C to reach a low specified voltage v is given by: $t = \left(\frac{v}{V}\right) \cdot T$. This approximation is within 6 percent of the exact time, as long as v is less than 10 percent of the applied voltage V.

CR1,CR2	1N914, 1N4001, or any similar silicon diode.
R2	For higher R3 current drain, the value of R2 is lowered, as described in the text.
R3	Bias adjustment potentiometer in existing amplifier.
R4,R5	Voltage divider to provide about −15 volts to the switching transistors. The current required depends on the value of R2. R4 can be the bleeder resistor in the existing bias supply. The lower end of R4 is lifted from ground and R5 is inserted.
Q1	Any PNP type with 40 V or higher rating; see text.
Q2	Any PNP type with 300 V or higher rating, see text.

(part of fig. 7)

CR1,CR2	1N914, 1N4001, or any similar silicon diode.
Q1	2N4401 or any similar NPN type.

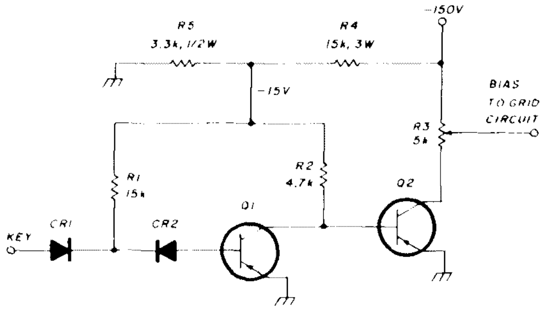


fig. 5. Tetrode amplifier bias switch. Values shown are typical for an amplifier of about −150 volts standby bias, such as a 4CX1000A. Rf filtering should be added, as noted in fig. 3.

listed above (for example, the circuit shown in **fig. 5**), the bias resistor R4 will have the value 15 k. Thus, we obtain

$$C = \frac{T}{R} = \frac{750\ ms}{15\ k} = 50\ \mu F \qquad \textbf{(4)}$$

Although one could calculate all this precisely, the final adjustment is best made empirically with an oscilloscope, as described below.

Now that we have the amplifier delay timing capacitor chosen, we can work on the antenna relay hold-in timing. On voice, one usually stops talking a fraction of a second before letting up the PTT switch. The delay is provided by our human reaction time, which is pretty slow compared to the speed of the electrons we're pushing up to the antenna. Still, one might release the PTT button in the middle of the last syllable, or take the foot off the foot switch while keying, and we have to provide for any such possibility. A good exciter continues to transmit for 3 to 5 milliseconds after the key is let up; this allows gradual decay of the keying waveform and prevents key clicks. If the antenna relay opens during this time, arcing will result, and in the case of QSK operation, key clicks will be generated.

For these reasons we provide a short delay in opening of the antenna relay when the PTT line is opened. In **fig. 3**, this is done with C1 at the base of Q1 in the relay switching circuit. When the PTT line is opened, Q1 won't turn on until C1 charges through R1 up to about −1.2 volts. This is 8 percent of the applied −15 volts, so we need a time constant T = RC about 12.5 times the required delay. For a 6-ms relay hold-in time, T = 75 ms will be about right. If R1 is 15 k, C1 will need a value of C = T/R = 75 ms/15 k = 5 μF.

antenna relays

Since the best bargains for coaxial relays on the surplus market, or at swap meets, are 24-volt dc types, **fig. 3** shows the circuit for these. The dc relays offer the advantages of quiet operation, solid-state control, and the convenience of using the relay supply to power the sequencing circuit. However, the circuit is easily adapted for an ac antenna relay by adding a small reed relay as shown in **fig. 6**. The reed relay switching time is quite small compared to that of the coax relay. We can add a few milliseconds to our computations, or just let it be absorbed in the final scope test.

Because of the high cost of antenna relays, I've followed the old-fashioned custom of using only one relay, at the amplifier output, with the receiver antenna line running to a separate jack on the exciter. This minimizes losses on VHF and alleviates the need for double

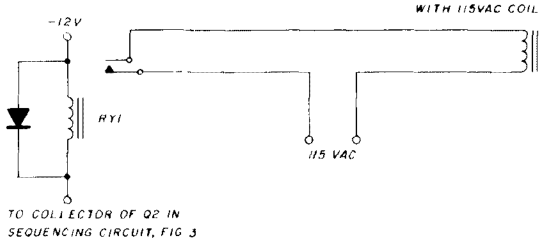


fig. 6. Interface for ac-operated antenna relay. RY1 is a 12-volt reed relay; other coil voltages may also be used.

relays on every preamplifier, attenuator, transverter, and driver down the line. This method is also highly recommended by some GaAsFET preamplifier manufacturers for safest operation. However, if you want to use two relays, switching the input and output simultaneously, just connect the coils in series or parallel, depending on the operating voltage available.

In the complete sequencing circuit shown in **fig. 3**, both the relay switch and amplifier switch are limited to 1-mA closed-circuit current, but the circuit as a whole requires the PTT line to sink 2 mA. The design standards can be implemented a bit loosely; in fact, the 1-mA limit was chosen for just this reason. If each individual circuit conforms to this limit, then any reasonable number of such circuits can be tied in parallel, and the total current will remain small.

In one of my relay sequencing circuits, extra protection is provided by inserting one set of the coax relay auxiliary contacts at the input to the amplifier delay

circuit at the base of Q3 in **fig. 3**, and the other set at the output at the collector of Q4. This keeps the amplifier disabled in the event of failures such as an open relay coil or a shorted or open transistor. This also provides some mechanical delay so that C1 need provide delay only during the bounce time. However, this mechanical method doesn't eliminate the need for the amplifier sequencing circuit. Oscilloscope tests on typical antenna relays show considerable antenna contact bounce times, continuing long after the auxiliary contacts close. Incidentally, the "hot-shot" method (providing double the coil voltage for about 50 ms) often seems to make the bounce worse!

amplifier switching

For tetrode amplifiers with negative grid bias standby switching, amplifier switching is done with a separate switching circuit installed in the amplifier, as shown in **fig. 5**. In principle, the amplifier bias adjustment control could be connected directly to the collector of Q2 in the sequencing circuit of **fig. 3**, but this would have several disadvantages. The voltage rating of Q4 would have to be high enough to handle the full standby bias of the amplifier, as high as −300 volts or more. This high voltage would be on the cable between the amplifier and the sequencing circuit, violating the standards set forth at the opening of this article. If the control lines of both the driver and final amplifier are tied together at Q4, the −300 volts from the amplifier would appear at the driver switching circuit and in the station band switch. The isolating diodes would have to be the high-voltage type and there would be dangerous voltages in unexpected places. I much prefer to have the bias switching circuit inside the amplifier, even though it may seem a bit strange to find four transistors between the PTT switch and the amplifier bias circuit. All but the last one — a required high-voltage type — are inexpensive.

For amplifiers with screen voltage standby switching, a small reed relay with a solid-state driver can be installed in the amplifier. For zero-bias triode amplifiers, the solid-state interface circuit shown in **fig. 7** may be used.

connection to the exciter

The PTT jack on the sequencer can be connected in parallel with the PTT line of the exciter if the exciter PTT line is also negative and isolated. If the exciter PTT line is negative but not isolated, isolation can be easily provided by using the basic circuit of **fig. 2**, with no timing capacitors. If the exciter PTT line is positive, and you want to use negative switching for most gear in the shack, the interface circuit shown in **fig. 7** can be used. For full break-in, the exciter can be delayed using another two-transistor switching circuit.

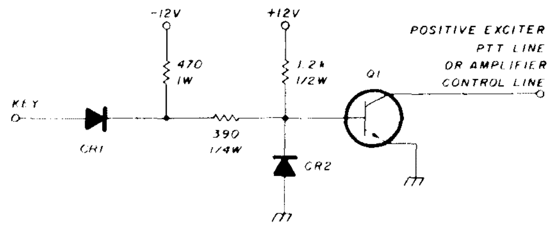


fig. 7. Interface for positive switching. This circuit will enable the negative switching sequencing circuit to control a positively-switched triode amplifier bias standby circuit, an exciter positive PTT circuit, or a relay energized with a positive voltage. It will sink more than 100 mA. Rf filtering should be added as noted in the caption for fig. 3. To reduce the current and voltage on the keyline, to conform with the standards suggested in the text, insert the basic circuit of fig. 2, without timing capacitors, in place of diode CR1.

testing and adjustment

The antenna relay can be tested to determine the actuating and bounce time before building the sequencing circuit, but it's easier to build the circuit using estimates of the delays required and then test the whole system afterwards. An amplifier delay of 50 ms and a relay hold-in time of 10 ms would be good figures to start with.

One possible test setup using a dual-trace triggered scope is shown in **fig. 8**. Although this illustration shows a battery, any available voltages from test supplies can be used. The antenna relay is controlled by the sequencing circuit, but the amplifier isn't used for the test. The external scope trigger connection, connected to the PTT line, is used. Thus the left edge of the scope trace represents closing of the PTT line. A foot switch, straight key, or push-button on the PTT line is convenient for repeated, manually triggered tests. The closing and opening transitions can be observed separately by changing the trigger polarity. One trace is used for the antenna relay contacts, and the other for the amplifier switching circuit. The testing is done with very small voltages and currents, so no damage results while you try different timing capacitors or parallel combinations of whatever capacitors are on hand in an effort to obtain the desired delays.

The timing capacitors should be selected so that the amplifier switch doesn't turn on until about 5 ms after the relay contacts cease bouncing and the contacts remain closed until about 10 ms after the amplifier shuts down. After initial adjustment, the antenna relay contact test current can be increased to several amperes; more bounce sometimes appears.

A single-trace scope can be used to see what's happening at two or more different places simultaneous-

ly, although it requires the special test circuit shown in **fig. 9**. A triggered sweep is still needed. The battery and the resistors establish various voltages, which the relay contacts and the amplifier switching circuit alter in such a way that can be observed on the scope. With the PTT line open, −9 volts will be seen on the scope. It stays at −9 volts while the relay contacts close. As soon as the relay closes, it climbs to −6 volts, then to −3.6 volts when the amplifier switching circuit turns on. If the amplifier switch turns on before the antenna relay closes, the trace will climb to −4.5 volts without going through the −6 volt stage, indicating that more amplifier delay is needed. Contact bounce before the amplifier switch turns on is seen on the scope as a fluctuation between −9 and −6 volts. Contact bounce after the amplifier switch turns on (to be avoided!) is seen on the scope as a fluctuation between −3.6 and −4.5 volts. Now when the PTT line opens, the amplifier switching circuit turns off instantly; the trace drops to −6 volts and stays there while the relay holds in, then drops back to the full −9 volts.

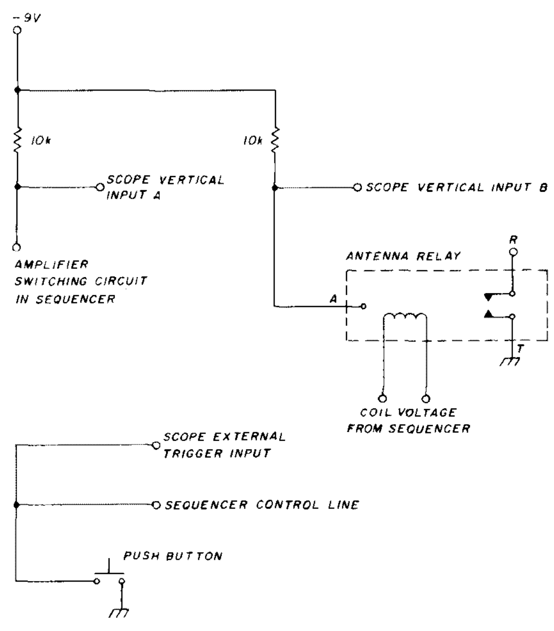


fig. 8. Test setup with a dual-trace scope.

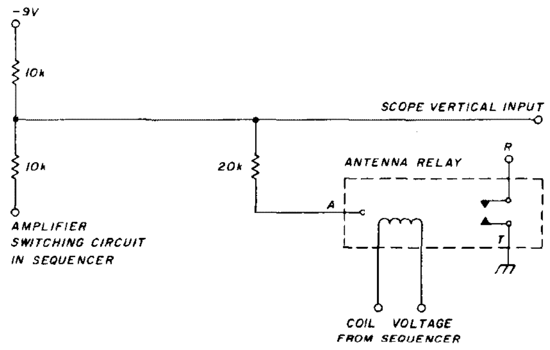


fig. 9. Test setup with a single-trace scope. Not shown is the trigger and PTT connection, which is the same as shown in fig. 8.

obtaining components

Inexpensive PNP transistors are available from the suppliers listed below.** For most circuit positions the 40-volt, 200-mA 2N3905 will do well. A good 24-volt relay driver is the slightly more expensive 120-volt 2N5400. Rated at 600-mA collector current, it will handle a 100-mA relay coil current with a nice safety factor. For higher coil current, such as we'd have with relays in parallel or 6-volt relays, the MPS-U57 (rated for 2 amperes) can be used. For tetrode amplifier bias switching in the circuit shown in **fig. 5**, the 300-volt MPS-A92 is available from BCD Electro.** These choices of transistor types are quite arbitrary; any available PNP types can be used as long as you check the manufacturer's ratings and compare these with the circuit voltage and current requirements.

For the timing capacitors, it's essential to use only tantalum electrolytics rather than ordinary filtering types. Tantalum will remain stable, with negligible leakage, over a very long time. Tantalum electrolytics usually have a 10 percent tolerance, which is satisfactory for sequencing purposes. On the other hand, the ordinary aluminum types often have tolerance ratings such as −20 percent to +100 percent. Because of this, and their leakage and unreliability, they are unusable in this application. Notice that in these circuits the capacitors never see more than 1.2 volts, so inexpensive 6-volt units may be used. One source for tantalum electrolytics is, again, BCD Electro.**

performance

For several years I've used two of these units with two homebrew amplifiers. One uses a 4CX1000A on 1.8 through 50 MHz; the other uses push-pull 4-400A's at 144 MHz. There's no arcing at the contacts, and I believe the antenna relays will last a long time.

Many antenna relays have an inspection port at one end, with a snap-in cover, for checking the contacts and connectors, which can be cleaned or replaced if necessary. It's interesting to remove this cover, turn off the shack lights, and watch for arcing. Without the sequencing circuit, the arcing can be seen clearly

** BCD Electro, P.O. Box 830119, Richardson, Texas 75083. Parts also available from Circuit Specialists, P.O. Box 3047, Scottsdale, AZ 85257.

every time you push or let up the PTT button. (For this test I ran low power to avoid burning the contacts too badly.) The dark-shack visual method provides a good final check on the sequencing circuit; this was how I found out how important it was to allow for the contact bounce time.

The sequencing circuit will protect the relay against contact arcing as long as there's a proper load on the antenna terminal. If a proper load is absent because of high SWR, antenna failure, feedline failure, or parasitics, the rf voltage could reach a high level and arcing could result between the transmit contact and the grounded relay shell. To protect against this, rf voltage limiting can be used with the circuit shown in reference 1. This circuit senses the rf voltage from the relay terminal to ground and uses the exciter ALC system to keep the amplifier output level below the arcing point. If the relay and sequencing circuit are built into the amplifier, all these protection circuits can be combined on one circuit board with an ALC circuit from reference 2 or 3.

references

1. M. Mandelkern, KN5S, "High SWR Protection for Transceivers and Amplifiers," *CQ*, May, 1980, pages 63-65.
2. M. Mandelkern, KN5S, "ALC for Class AB_1 Amplifiers," *QST*, July, 1986, pages 38-39, 47.
3. M. Mandelkern, KN5S, "ALC for Triode Amplifiers," Technical Correspondence, *QST*, December, 1986, pages 46-47.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

impedance-matching techniques

Because hardly a month goes by that I don't receive at least one question about impedance matching, this month's column will first address the subject generally and then describe some specific techniques.

impedance matching in general

When impedance matching is discussed, it usually refers to matching to an antenna. Often the only question is "How do I get a low VSWR?"

For years Amateurs have had the notion that if the VSWR isn't close to unity (1:1), valuable power is being lost. They seldom consider the insertion loss of the transmission line, the accuracy of the measurement gear, or the mismatch loss (if any).

It's true that if the VSWR on a transmission line isn't 1:1, there's an additional line loss over and above that of the insertion loss of the feed line.[1] This is often referred to as "mismatch loss." For many years a graph published in several Amateur journals and the ARRL's *Antenna Book* has shown how to estimate the mismatch loss if the VSWR at the load and the nominal insertion loss of a transmission line are known.[2] Because I didn't know how precise it was, and because using it involves a two-step addition process (another possible source of error), and because it doesn't include low transmission line losses such as typically encountered at EME, I haven't had much confidence in it.

Thanks to Dick Turrin, W2IMU, I now have the mismatch loss mathe-

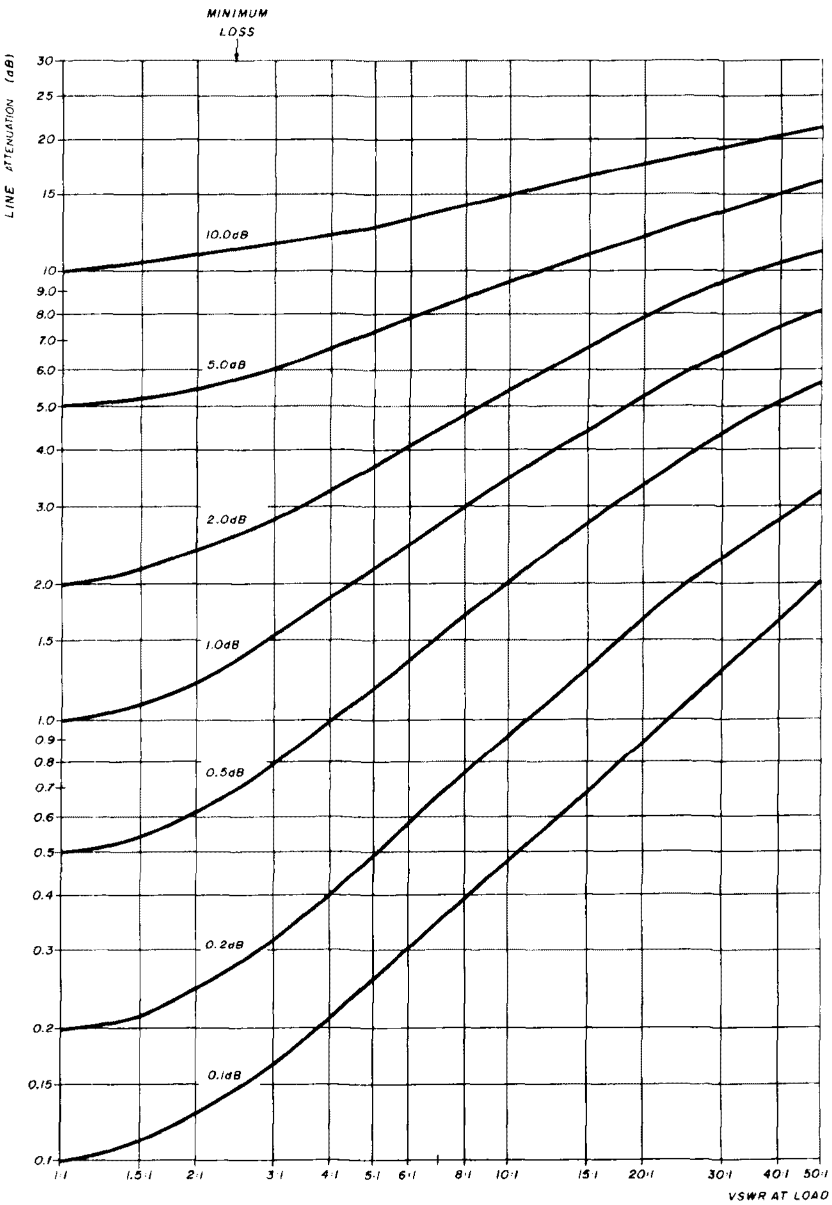


fig. 1. Total insertion loss in a transmission line terminated in a mismatch (see text).

matical equations, but they are lengthy. Dick pointed out to me that a mismatch loss graph using a different format was published in the 1940s.[3] Sure enough, I'd had the information in my files all these years and hadn't noticed it!

I've verified the math. The older and, in my opinion, more useful graph for mismatch loss is shown in **fig. 1**. Note that this graph stands alone, in that the loss indicated is the total loss, not just an incremental amount which then has to be added to the nominal insertion loss. As with the former graph, you still have to know the VSWR at the load as well as the nominal insertion loss of the transmission line. The latter quantity, however, is readily available.[1,2]

For example, using **fig. 1**, if the VSWR at the load is 5:1 and the nominal transmission line insertion loss is 0.2 dB, the total insertion loss — including the mismatch loss — will be 0.5 dB. Furthermore, if the VSWR at the load is 3:1 and the nominal insertion loss of the line is 5 dB, the total insertion loss will be 6 dB. I feel that **fig. 1** is easier to use and more realistic than the graph most Amateurs are presently using.

Impedance matching is especially important nowadays because of the proliferation of solid-state power amplifiers that will shut down or decrease power in the presence of VSWR above 1.5 or 2:1. However, the subject of impedance matching extends beyond antenna systems, since impedance matching can also refer to matching into or out of a low-noise, medium, or high power amplifier. Impedance matching can be narrowband as well as broadband and between resistive or reactive loads.

categories of impedance matching

Before we go any further, we should discuss what I feel are the three major categories of impedance matching: nonreflective, conjugate, and optimum source. Nonreflective matching is probably the most common type. In this scheme, an impedance matching network or "antenna tuner" is placed somewhere in the line between the source and load. This network is then tuned for minimum VSWR looking into the load. In a worst-case scenario, a large attenuator could be placed between the source and load to yield a good impedance match. (More on this shortly.)

Conjugate matching is often used in the design of solid-state power amplifiers where gains are typically low and therefore losses must be kept at a minimum, both in the input matching network and in the components involved.[4] In order to accomplish a conjugate match, all reactive components must be cancelled and the resistive component of the load made equal to the input line impedance.[5] Conjugate matching is often used in applications where wider bandwidth or no tuning is desired.

Optimum source matching usually refers to providing the impedance required for best operation of the load. In the case of a vacuum tube power amplifier, if a conjugate output match is used, at least one-half of the rf output power generated would have to be dissipated in the tube — a very inefficient condition.[5] Therefore, conjugate matching is usually not used in high-power amplifier designs.

In a similar manner, the input circuit of a low-noise preamplifier is often tuned to an impedance that produces the lowest noise figure, which seldom yields a good impedance match. Therefore a device or circuit that requires optimum source matching will usually have a moderate to poor input and/or output VSWR.

simple impedance-matching techniques

There are many ways to perform impedance matching. Resistors, transformers, reactive elements, transmission lines, and stubs are some commonly used VHF/UHF/SHF techniques. The optimum choice depends on whether the load is resistive or reactive, whether any insertion loss is allowable, and how broadband the match must be.

If loss isn't a problem, the load is resistive and doesn't have to see an impedance match looking back at the source; a simple resistor or resistor network is all that's necessary for a wideband impedance match. Several examples of resistor matching are shown in **fig. 2**.

In **fig. 2A**, the impedance of the amplifier must be resistive and less than the source impedance. The matching resistor, R, will be the difference between the source and load impedance. For example, if you want to match a source of 50 ohms and the load is 40 ohms, R should be 10 ohms.

If the load impedance is higher than the source, use a shunt resistance as shown in **fig. 2B**. With a load of 75 ohms, the shunt R will have to be 150 ohms to provide a match to a 50-ohm source. In either case, the matching resistor will dissipate power and decrease overall gain. Furthermore, the source will see a good impedance match but the load looking back toward the source will see a mismatch. The larger the impedance difference between the source and load, the larger the insertion loss and the lower the gain.

Sometimes it's desirable to have both the source and load see a good impedance match. In this case, the so-called "minimum loss pad" can be used for impedance matching (see **figs. 2C** and **2D**). This type of impedance matching provides a match looking both ways but has a higher insertion loss than the single resistor matching shown in **figs. 2A** and **2B**.

For example, using **fig. 2C** with a source impedance of 50 ohms and a load of 40 ohms, R1 should be 22.4 ohms and R2 89.4 ohms. The overall insertion loss will be 4.2 dB. If the load impedance is higher than the source, use the circuit in **fig. 2D**. With a source impedance of 50 ohms and the load at 75 ohms, R1 will be 86.6 ohms and R2 43.3 ohms. The overall insertion loss will be 5.7 dB.

If gain is of no consequence, typical "T" or "PI" attenuator pads can be used for impedance matching as shown in **figs. 2E** and **2F**. If the at-

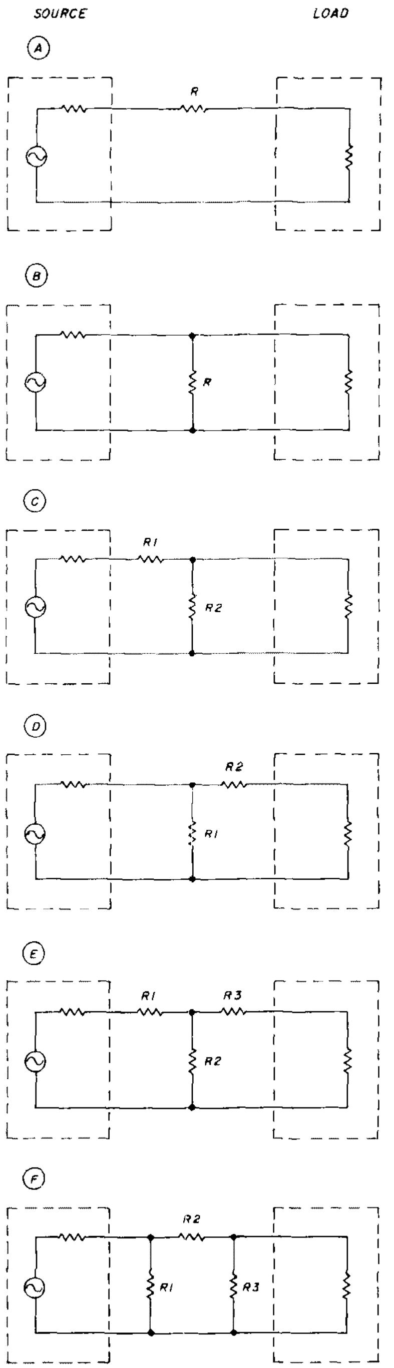


fig. 2. Different types of resistor matching for cases in which the source and load impedance are resistive: (A) source impedance is higher than load; (B) load impedance is higher than source; (C) minimum loss pad with source impedance higher than load; (D) minimum loss pad with load impedance higher than source; (E) typical symmetrical "T" pad attenuator; (F) typical symmetrical "PI" pad.

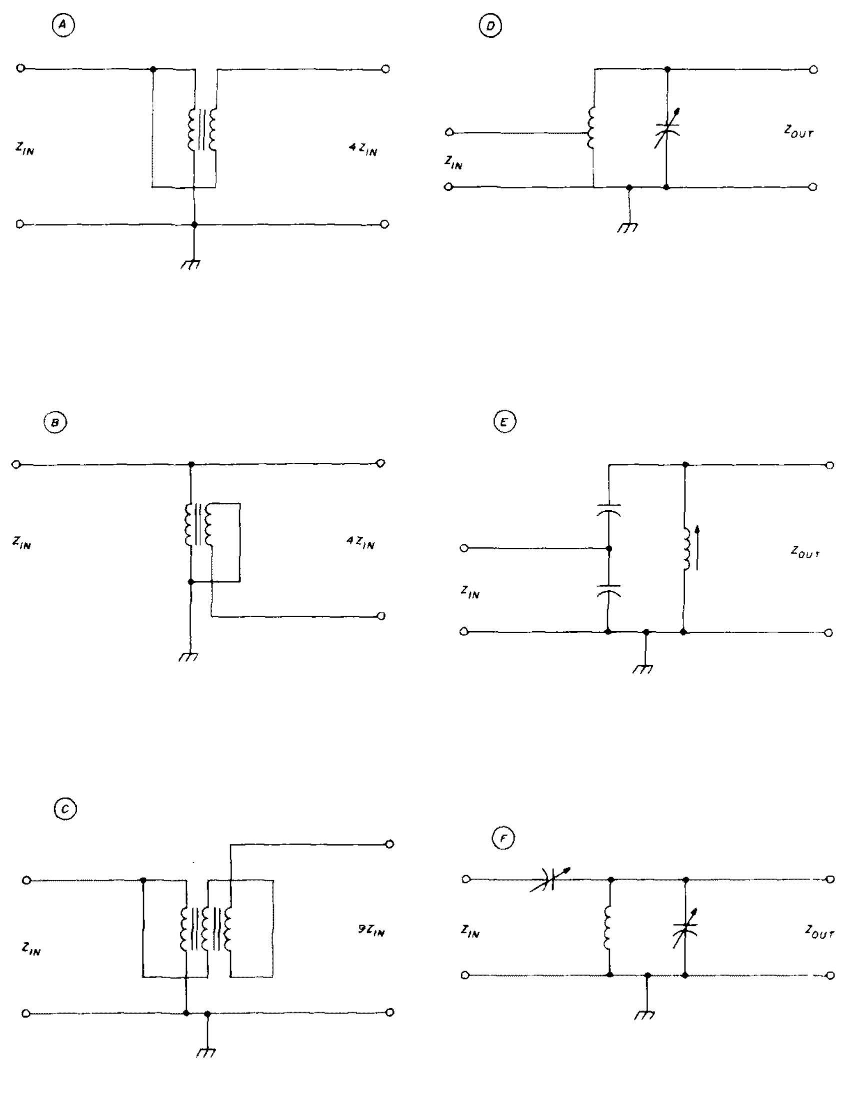


fig. 3. Typical transformer matching techniques: (A) simple 4:1 bifilar wound transformer; (B) typical 4:1 balun transformer; (C) trifilar wound 9:1 transformer; (D) typical resonant step-up/step-down transformer; (E) step-up/step-down transformer using tapped capacitor configuration; (F) variable tap transformer.

tenuation of the pad is high enough, for example 10 dB, the source and load will typically see a VSWR equal to or better than 1.2:1. Values for a 10-dB pad are 26, 35, and 26 ohms for R1, R2, and R3, respectively, in **fig. 2(E)** and 96, 71, and 96 ohms, respectively, in **fig. 2(F)**.

Finally, even lossy coax cable can act as an attenuator. For example, RG-58A/U coax has a loss of approximately 11 dB per 100 feet at 400 MHz. Therefore, about 90 feet of RG-58A/U would make an excellent 10-dB attenuator for the 70-cm (432 MHz) band with a power rating of 85 watts to boot.[1] Equations for designing minimum loss and matched attenuator pads are available in most design handbooks.[6] Typical computer programs are also available.[7]

transformer matching

Another method of impedance

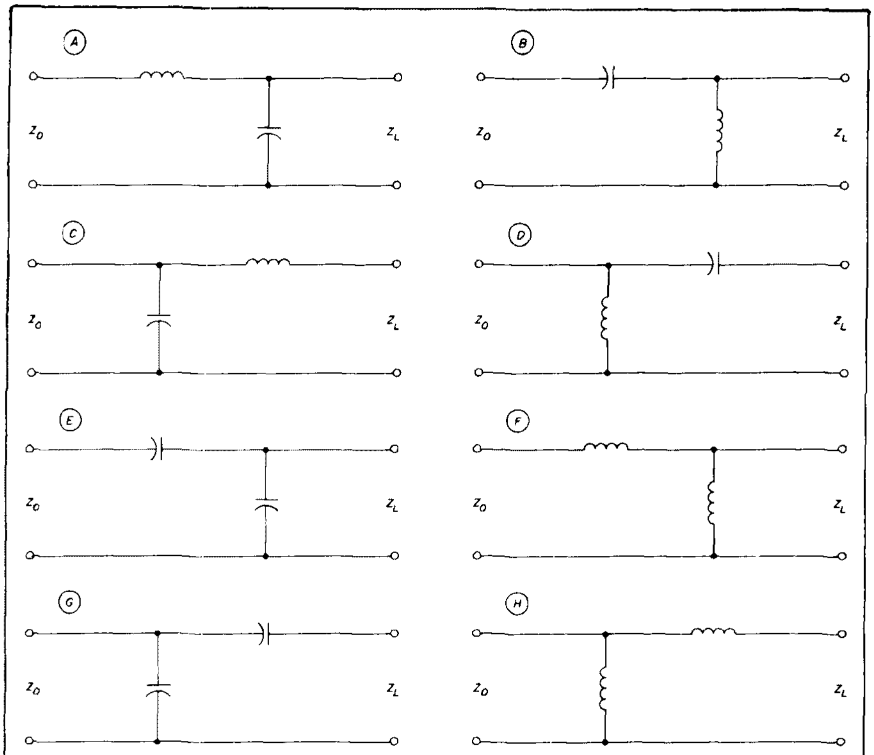


fig. 4. These eight "L" networks can be used to match any impedance to any other impedance (see reference 9).

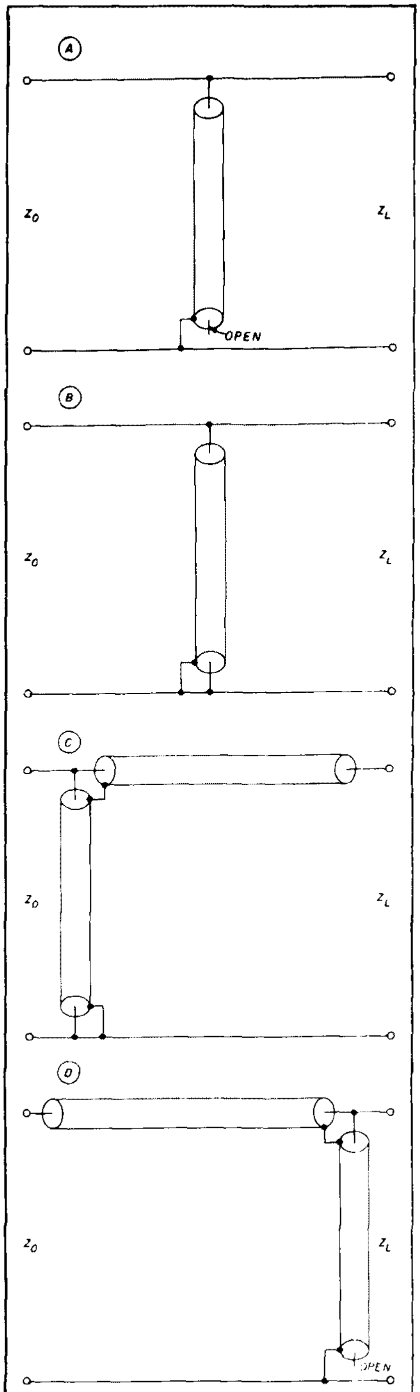


fig. 5. Typical stub impedance matching networks: (A) open shunt stub; (B) shorted shunt stub; (C) shorted shunt and series transformer; (D) series transformer and open shunt stub.

matching is through the use of transformers. The 4:1 transformer is particularly popular with Amateurs. It will conveniently match a resistive source to a resistive load that is four times the impedance. A bifilar wound transformer is often used, as shown in **fig. 3A**. This technique was recently suggested by Bob Sutherland, W6PO, for matching out of GaAsFET amplifiers.[8] Bifilar wound transformers are also very popular for toroidal baluns (**fig. 3B**). Trifilar wound transformers can also be used to match resistive impedances that are a ratio of nine times (**fig. 3C**).

Another popular form of transformer is the resonant step-up/step-down type that is often used at the input of low-noise receivers. It has many forms, but those shown in **figs. 3D** and **3E** are the most popular. **Figure 3F** is a somewhat simpler but more obscure transformer configuration that's popular where the goal is to optimize the impedance in the circuit without *changing taps or components.* Resonant transformers are often used in reverse to match the output of a high-impedance small signal amplifier to a lower impedance. Other types of transformers using coaxial techniques will be discussed shortly.

reactive impedance matching

So far I've been discussing mostly resistive matching networks. At the lower VHF/UHF frequencies, especially when low-loss impedance matching is required over only a narrow bandwidth, simple "L" networks using inductors and capacitors are often used, especially when the load impedance is reactive.

This is probably the time to mention the venerable "Smith Chart," a tool used mainly by professionals to impedance match from any one impedance to any other impedance if the impedances of the source, load, and reactive components are known.[9] Smith points out in Chapter 10 of his *book that any resistive impedance, Zo,* can be matched to any complex impedance, Z1, using a simple L-net-

work. The eight required circuit topologies are shown in **fig. 4**. Smith shows the recommended network based on the portion of the Smith Chart where the load is present.

stub matching

Impedance matching can also be accomplished using coaxial stubs. The most common configurations are the open (**fig. 5A**) and the shorted (**fig. 5B**) shunt types. In most cases the stub is less than one-quarter wavelength. If a shunt stub isn't sufficient to complete the match, a tandem transmission line, also usually less than one-quarter wavelength, may be added ahead of or behind the shunt stub as shown in **figs. 5C** and **5D**. The Smith Chart is particularly useful for performing stub matching.

Use of the Smith Chart has been described many times in the Amateur literature[10,11,12] so I won't dwell on it here. Instead, I'll refer you to these references and use the rest of this month's column to show simple impedance-matching techniques that can be easily implemented by Amateurs.

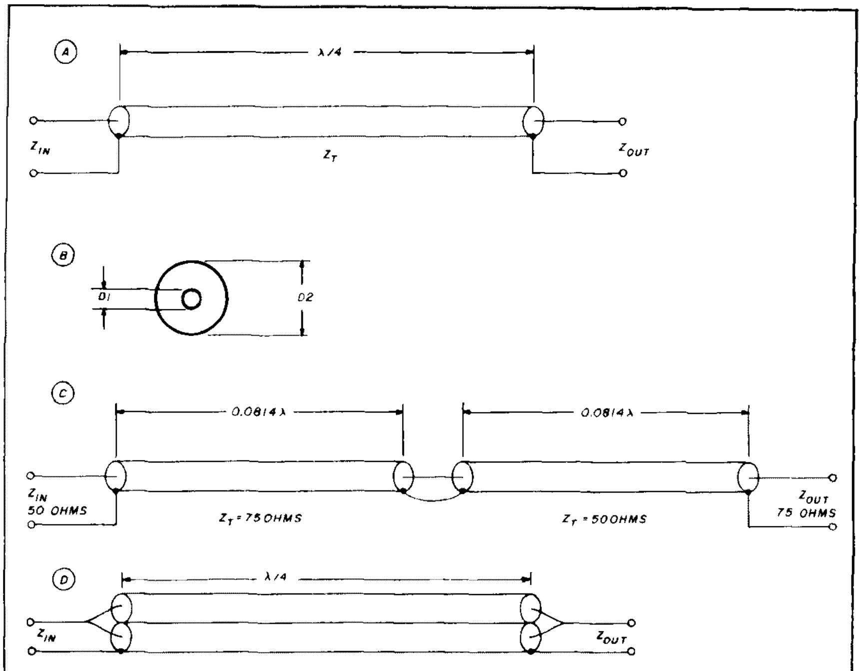


fig. 6. Typical coaxial transformers: (A) quarter-wavelength transformer; (B) elements of the physical properties of a coaxial line; (C) example of a 50- to 75-ohm non-synchronous transformer. (D) Coaxial cables can be paralleled to half the nominal impedance.

coaxial transformers

Probably one of the most widely used impedance matching techniques in the VHF/UHF spectrum is the "quarter-wavelength transformer" as shown in **fig. 6A**. In its simplest form it can match virtually any two resistive impedances. The impedance of the line is the geometric mean between the input and output impedances as shown below:

$$Z_t = \sqrt{Z_{in} Z_{out}} \qquad \textbf{eqn. 1}$$

Where Z_t is the impedance of the quarter-wavelength transformer, Z_{in} is the input impedance, and Z_{out} is the output impedance, all in ohms. For example, let's say that we want to match a 50-ohm resistive line to a 75-ohm resistive line. Using equation 1, the optimum impedance of the quarter-wavelength transformer, Z_t, is 61.24 ohms.

The length, as stated above, must be one-quarter wavelength at the operating frequency. This can be determined using equation 2:

$$L = \epsilon_r (2951/f) \qquad \textbf{eqn. 2}$$

Where L is the length in inches, ϵ_r is the dielectric constant, 1.0 for air, and f is the frequency in MHz. Therefore a quarter-wavelength transmission line at 432 MHz using air dielectric is approximately 6.83 inches long.

Now all you have to do is to build a coaxial line section one-quarter wavelength long that has a characteristic impedance of 61.24 ohms. The impedance can be determined using equation 3:

$$Z = 138 \log (D2/D1) \qquad \textbf{eqn. 3}$$

Where Z is the impedance of a coaxial line, D1 is the outer diameter of the inner tubing, and D2 is the inner diameter of the outer tubing (see **fig. 6B**). For an impedance of 61.2 ohms, the ratio of D2/D1 is approximately 2.78:1.

A suitable coaxial transmission line can be made using hobby shop brass or copper tubing.[13] Half-inch household plumbing uses copper tubing that has an approximate inside diameter of 0.532 inches. Therefore, a 3/16-inch outside diameter tube, such as you'll find in hobby shops, would make a good match for the inside tube in this particular application.

Yet another transformer matching scheme — the "non-synchronous" transformer — is an outgrowth of the work of Frank Reiger, OD5CG[14,15,16,17] offering similar matching properties. **Figure 6C** shows a particularly fine example of this kind of transformer using two lengths of coax of the same impedance as that to be matched but inverted. No longer is there a need for an "oddball" line impedance. The overall length is 0.1628 wavelengths, which is 35 percent shorter than an equivalent quarter-wave transformer.

Another trick is to parallel coax. For instance, if two identical pieces of coax are paralleled, the new impedance is half the individual value (**fig. 6D**).

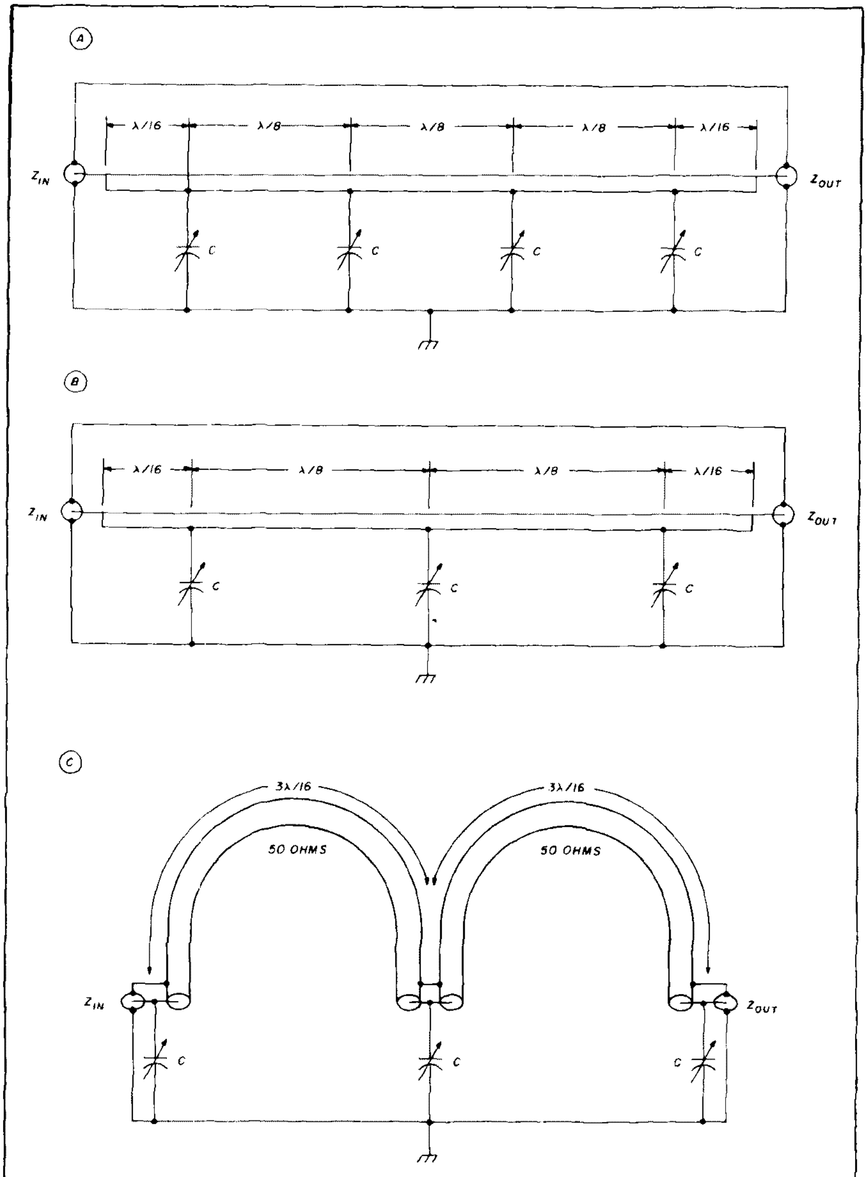


fig. 7. Examples of coaxial type antenna tuners: (A) half-wavelength adjustable transformer; (B) three-eighths wavelength adjustable transformer; (C) three-eighths wavelength adjustable transformer using coaxial cable.

Therefore, two quarter-wavelength pieces of 70-ohm coax in parallel would equal 35 ohms and could be used to match 25 ohms to a 50-ohm line. Likewise, two quarter-wavelength pieces of 50-ohm coax in parallel would have an impedance of 25 ohms and would be good for matching from 50 to 12.5 ohms.

variable impedance matchers

Some of the matching techniques just described are fine, especially when the impedances to be matched are resistive. But what do you do when you want to impedance match to a reactive load? The answer is that you need some sort of antenna tuner. At VHF/UHF/SHF frequencies this doesn't have to be the coil and variable capacitor type typically used at hf. Instead, you can build a very simple tuner using a section of coaxial line with a few small variable capacitors properly spaced along the line and shunted to ground.

Figure 7 shows some recommended types of coaxial line impedance matchers. The first, **fig. 7A**, is the most complex.[18] Basically speaking, a half wavelength of 50-ohm line is constructed in a trough, enclosure, or even in a microstrip line. Four variable capacitors are shunted to ground along the line at specific wavelength intervals as shown. **Figure 7B** shows a slightly simpler three-eighths wavelength matching scheme that probably has a little less tuning range.[19]

Figure 7(C) shows another scheme developed by one of my former colleagues, Dick Thurston. It originally used standard coax cable, so it has slightly higher loss than the schemes just described, but it's inexpensive and easy to construct. If standard coax is used, the line sections must also be shortened because of the dielectric constant of the line. At lower frequencies the coax can be coiled up. Thus a very compact, inexpensive impedance-matching transformer is possible.

The typical maximum capacitance required for the tuners shown in **fig. 7** can be determined empirically or by using equation 4 below:

$$C_{max} = 9{,}000/f \qquad \textbf{eqn. 4}$$

Where C_{max} is in pF and f is in MHz. For example, 60 pF and 20 pF are typical maximum values for 144 and 432 MHz, respectively. In any case, the minimum capacitance should be no greater than 10 percent of C_{max} or 6 and 2 pF, respectively.

In all of these coaxial type tuners, the capacitors must be physically small, have low inductance, and have very short leads. Mica compression trimmers similar to the types used in transistor power amplifiers are quite suitable. Air variables such as the E. F. Johnson type "U" or piston trim-

mers made by Johanson and others are excellent for low-power applications, especially at UHF frequencies.

On 220 MHz, I have a cathode-driven final that has a moderate input VSWR. Normally this wouldn't require any attention, but my solid-state driver doesn't care for the input mismatch. Hence a tuner similar to the one in **fig. 7C** is now used with three 4- to 40-pF mica compression trimmers and two pieces of RG-58A/U coax, each 6-1/2 inches long. This tuner now provides a good input VSWR to my final.

All that's necessary to adjust this kind of tuner is to connect it in the line with a VSWR bridge (**fig. 8A**). First set all capacitors at minimum capacitance. Then tune one capacitor at a time, starting with the one closest to the load, alternating combinations until a satisfactory match is obtained. It probably takes less time to do than explain it!

One final thought on coaxial tuners. As I pointed out earlier, additional mismatch loss will be incurred if a transmission line has even a moderate (2:1 or higher) VSWR. However, if a tuner is placed close to or at the load instead of the source, the mismatch loss may be entirely eliminated — a double bonus!

UHF/SHF tuners

When you go higher in frequency, capacitors become inductive; consequently, the tuners mentioned above are probably usable only to about 1.3 GHz, provided that care is taken to select a good capacitor type. Above 1 GHz, impedance matching is often accomplished using variable shorted (or open) stubs, "line stretchers," and dielectric slug tuners.

Figure 9A shows the simplest type of stub tuner, usually fitted with a connector so that it can be easily inserted into a coaxial line, perhaps via a "T" fitting. If the stub won't decrease the VSWR sufficiently, a line stretcher (**fig. 9B**) may be inserted between the load and the stub so that the distance of the stub tuner from the load can be varied (**fig. 9C**).

Another common type of impedance matcher is the double-stub tuner (**fig. 9D**), which consists of two variable-length shorted (or open) stubs typically adjustable up to one-half wavelength and separated by the distance, D, one-eighth to three-eighths of a wavelength at the operating frequency. Double-stub tuners can match impedances only over a limited frequency range.

The triple-stub tuner shown in **fig. 9E** is more complex to use because it has more independent variables than the double-stub tuner. However, it will virtually match any impedance to any other impedance. It has one major drawback in that some settings will incur very high losses, so use it accordingly.

Stub tuners are in wide use, particularly where a quick impedance match is desired until a final circuit can be configured. However, most stub tuners employ some type of mechanical short circuit. This short sometimes increases insertion loss or causes intermittents due to high circulating currents, especially after extended tuner use. The construction of a suitable double-stub tuner is described in reference 20. Both double and triple stub tuners are manufactured by many companies, so they often turn up at flea markets.

Because of the mechanical problems associated with stub tuners as just described, dielectric slug tuners are sometimes used. A typical slug tuner is shown in **fig. 9F**. It usually consists of a 50-ohm air-type transmission line with electrical quarter-wavelength pieces of low-loss dielectric (such as PTFE/Teflon RTM) or metal slugs (covered with a low-loss insulating dielectric) placed along the line. Slug tuners don't have the tuning range of a stub tuner, but they will fit most applications and are usually easier to construct and use. Some recommended construction techniques for slug tuners are described in reference 21.

A variation on the slug tuner is the "multi-screw" tuner, which may be used in coax (**fig. 9G**) but is especially useful in waveguide (**fig. 9H**). It works on the same principle of operation as the coaxial tuner. The greater the number of screws available, the greater the tuning range. Brass or silver-plated screws are recommended, with appropriate nuts soldered to the housing for low-impedance, low-loss rf contacts. Some recommended construction techniques are described in reference 22.

Most of you are probably familiar with microstrip transmission lines which are very popular, especially above 1 GHz. Microstrip is often used where impedance matching is required. The quarter-wavelength transformer (**fig. 10A**) or shorted and open stubs (**fig. 10B**) are easily implemented. Microstrip is great for production equipment. However, it does require a thorough knowledge of the circuit elements and much tweaking with expensive test equipment before optimum performance can be achieved.

This explains the recent popularity — particularly above 2 GHz — of what I call the "empirical matching tuner." **Figure 10C** shows a typical configuration. A 50-ohm microstrip transmission line perhaps one-half wavelength long is etched on the pc board either ahead of or behind the device to be matched. Then thin narrow strips (0.1 to 0.5 inches wide) of brass or copper shim stock perhaps 0.05 to 0.25 wavelength long are slid along the line until an optimum match occurs.

When using this empirical technique, sometimes the size and/or shape of the metal strip has to be altered many times. Often more than

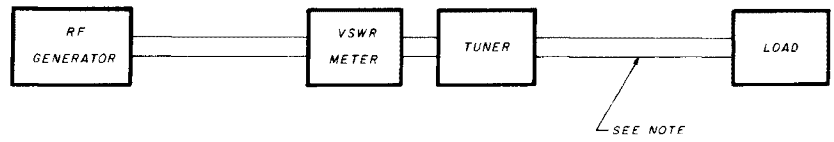


fig. 8. Typical VSWR test setup. Note that it's preferable to mount the tuner as close to the load as possible in order to decrease mismatch losses, as discussed in text.

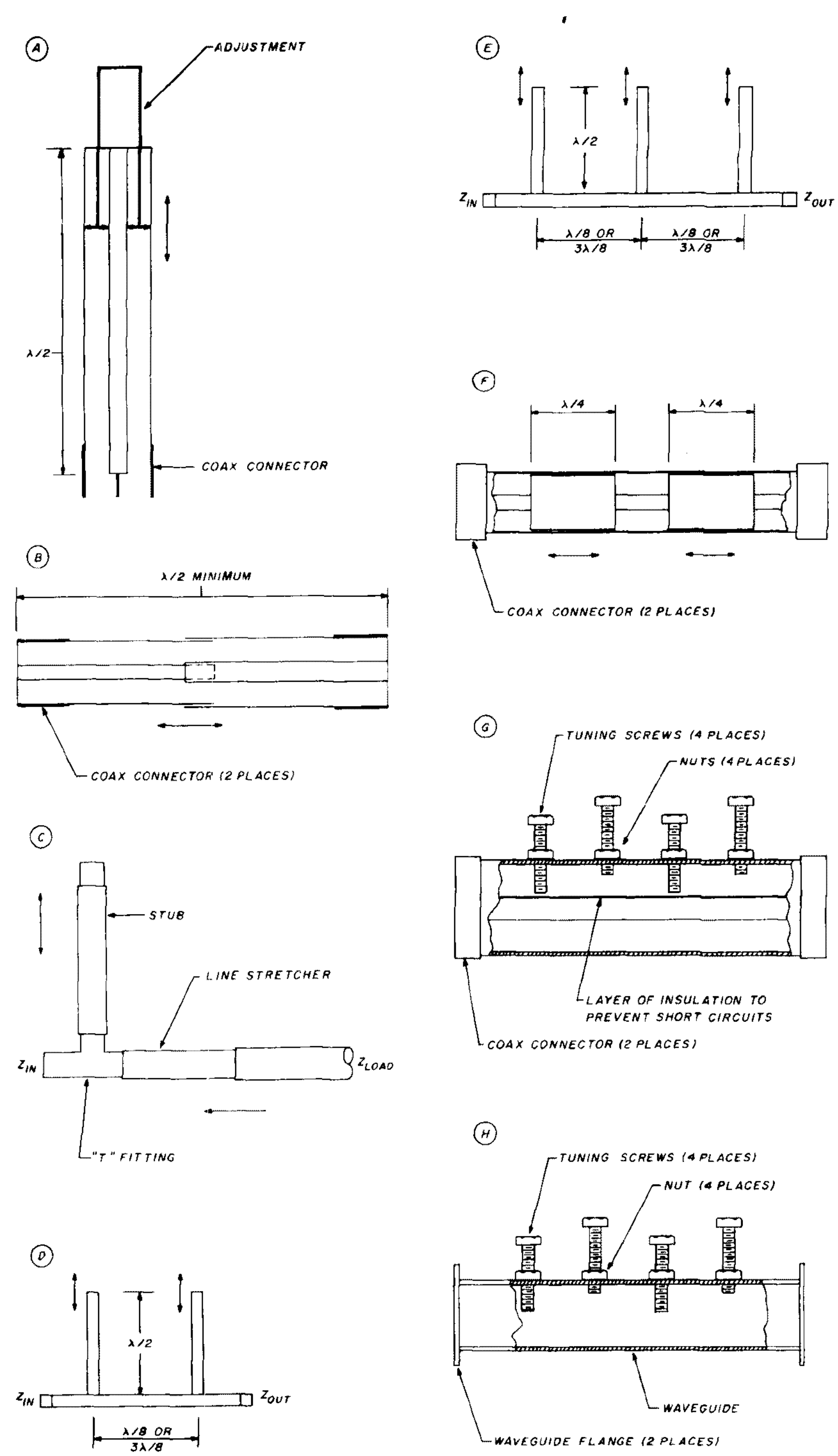


fig. 9. Examples of UHF/SHF tuners: (A) variable shorted (or open) shunt stub tuner; (B) typical line stretcher; (C) combination variable shunt stub and line stretcher; (D) typical double-stub tuner; (E) typical triple-stub tuner; (F) typical dielectric slug tuner; (G) multiple screw tuner; (H) screw tuner in waveguide.

one strip is required. These "tuners" can be slid along the main line with a small-diameter insulated material such as a wooden dowel from a cotton swab. When the optimum spot is located on the line, the strips are soldered in place and perhaps glued to the pc board so that they won't move. This approach is simple and inexpensive and can be quite effective.

wideband matching techniques

So far I've mentioned mostly narrowband matching techniques, since they're usually all that Amateurs need. Most wideband techniques require more hardware, several matching sections in cascade (rather than a single section, as previously discussed) and often have higher insertion loss.

Other wideband techniques involve the use of hybrid couplers, ferrite isolators, and circulators, but these usually aren't necessary in Amateur applications and are therefore beyond the scope of this month's column. For those interested, I'd recommend references 23 and 24 for some wideband impedance-matching transformers.

antenna impedance matching

By now you're probably wondering why I haven't covered any information directly related to antennas. The subject of antenna matching has been addressed many times in the literature. References 13 and 26 describe not only recommended techniques but also typical test equipment.

Basically, matching an antenna is largely a matter of setting up a measurement system similar to the setup in **fig. 8**. Then the length, spacings, and diameters of the driven element and matching section are adjusted until an optimum impedance match is obtained. If you have any specific questions about antenna impedance-matching techniques, let me know and they can be covered in a future column.

summary

The subject of impedance-matching techniques has been widely addressed

in Amateur literature. New techniques — some simple, some complex — are constantly being presented. The material presented in this month's column reflects a summary of some of the information that should be most useful for Amateurs, especially those interested in the VHF/UHF/SHF frequencies. I hope I've described some new or interesting technique that will be of help to newcomers and old-timers alike.

acknowledgments

I'd like to particularly thank Dick Turrin, W2IMU, for deriving the formulas necessary for me to calculate mismatch loss, and for providing appropriate references.

new records

Just as I completed this column, an important milestone in radio propagation occurred: the first two-way contact via sporadic E propagation on the 135-cm (220 MHz) Amateur band. As I've mentioned before, this has been a big plum, with at least two prior one-ways. (Yes, I was on one end of one of them!)

All that changed during the June ARRL VHF QSO Party, when sporadic E propagation was super on 6 and 2 meters in the southern portions of the United States. Finally, after a few unsuccessful attempts, on June 14, 1987, Bill Duval, K5UGM, of Irving, Texas (EM12MS) completed a two-way contact with John Moore, W5HUQ/4, of Orange Park, Florida (EM90GC), on 220.1 MHz — for a record 932 miles (1499 km). Both CW and SSB were used, and signals were much greater than S9. Congratulations to Bill and John. Another Amateur Radio propagation first! Now that it's been done, let's see how long it takes to do it again!

During this same contest, apparent double-hop sporadic E contacts took place on 2 meters. However, some of them that have been reported to me so far either were short of the present North American record (1891 miles or 3043 km) or were incomplete contacts. I would particularly like to hear from anyone who can better the existing record.

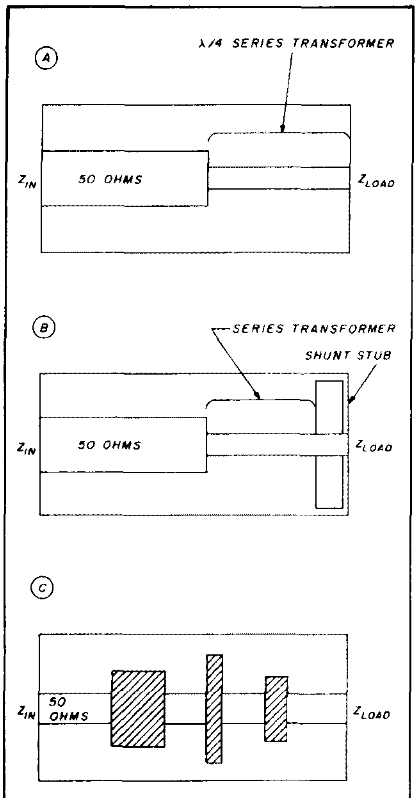


fig. 10. Examples of typical microstrip matching techniques: (A) series quarter-wavelength transformer; (B) series and shunt stubs; (C) empirical matching tuner.

important VHF/UHF events:

October 3-4	*International Region 1 UHF/SHF Contest, 70 cm and up*
October 4	*EME perigee*
October 9	*Predicted peak of the Draconids meteor shower at 0900 UTC*
October 10-11	*Mid-Atlantic States VHF Conference Warminster, Pennsylvania (Contact WA2OMY)*
October 17-18	*ARRL EME Contest, first weekend*
October 21	*Predicted peak of the Orionids meteor shower at 0830 UTC*
October 30	*EME perigee*
November 3	*Predicted peak of the Taurids meteor shower at 2200 UTC*
November 3	*Predicted peak of the Cassiopids meteor shower at 2100 UTC*

November 14-15	*ARRL EME Contest, second weekend*
November 17	*Predicted peak of the Leonids meteor shower at 1500 UTC*
November 24	*EME perigee*

references

1. Joe Reisert, W1JR, "VHF/UHF World: Transmission Lines," *ham radio*, October, 1985, page 83.
2. Gerald Hall, K1TD, *The ARRL Antenna Book*, available from *ham radio's* Bookstore; $8.00 plus $3.50 shipping and handling.
3. Theodore Moreno, *Microwave Transmission Design Data*, Dover Publications, 1958.
4. Joe Reisert, W1JR, "VHF/UHF World: Medium Power Amplifiers," *ham radio*, August, 1985, page 39.
5. M. Walter Maxwell, W2DU/W8KHK, "Another Look at Reflections – Part II," *QST*, June, 1973, page 20.
6. *Reference Data for Radio Engineers*, Sixth Edition, Howard W. Sams Company.
7. Joe Reisert, W1JR, and Gary Field, WA1GRC, "RF-CAD Electronics Design Program"; available for the IBM PC from *ham radio's* Bookstore; $39.95 plus $3.50 shipping and handling.
8. Joe Reisert, W1JR, VHF/UHF World: Low-Noise GaAsFET Technology," *ham radio*, December, 1984, page 99.
9. Phillip H. Smith, "Electronic Applications of the Smith Chart," McGraw-Hill Book Company, 1969.
10. Gerald L. Hall, K1PLP, "Smith Chart Calculations for the Radio Amateur – Part I," *QST*, January, 1966, page 22.
11. Gerald L. Hall, K1PLP, "Smith Chart Calculations for the Radio Amateur – Part II," *QST*, February, 1966 page 30.
12. Jim Fisk, W1DTY, "How To Use The Smith Chart," *ham radio*, November, 1970, page 16.
13. Joe Reisert, W1JAA, "VHF/UHF Techniques: Feeding and Matching Techniques for VHF and UHF Antennas," *ham radio*, May, 1976, page 54.
14. Frank A. Regier, "Impedance Matching with a Series Transmission Line Section," *Proceedings of the IEEE*, Volume 59, No. 7, July 1971, pages 1133-1134.
15. Frank A. Regier, OD5CG, "Series-Section Transmission-Line Impedance Matching," *QST*, July 1978, page 15.
16. Pat Hawker, G3VA, "Technical Topics: Transmission Line Transformers," *Radio Communications*, December, 1971, page 841.
17. Henry Keen, W5TRS, "Non-Synchronous Impedance Transformer," *ham radio*, September, 1975, page 66.
18. William L. Smith, W3GKP/A3GKP, "The C-Line Matcher," *QST*, September, 1968, page 23.
19. Robert D. Shriner, WA0UZO, "A Coaxial-Line Matcher for VHF Use," *QST*, July, 1969, page 20.
20. George Harterell, K6LK, "Double-Stub Tuner," *ham radio*, December, 1978, page 72.
21. Dick Turrin, W2IMU, "Technical Reports from the Crawford Hill VHF Club," available from W2IMU, P.O. Box 65, Colts Neck, New Jersey 07722 ($24.00).
22. A. B. Bereskin, "Multi-Screw Tuner for Any Mismatch," *Microwave Journal*, August, 1983, page 133.
23. George L. Matthaei, "Tables of Chebyshev Impedance-Transforming Networks of Low-Pass Filter Form," *Proceedings of IEEE*, August, 1964, page 939.
24. George L. Matthaei, "Short-Step Chebyshev Impedance Transformers," IEEE *MTT*, August, 1966, page 372.
25. Joe Reisert, W1JAA, "VHF/UHF Techniques: Matching Techniques for VHF/UHF Antennas," *ham radio*, July, 1976, page 50.

ham radio

return of the

360-degree propagation prediction

Improved coding combines 24-hour MUF and point-to-point programs

My February, 1987, article, "360-degree MINIMUF Propagation Prediction"[1] described a computer program for producing a 360-degree propagation prediction for any stated hour of the day. That article generated considerable interest in the program; unfortunately, there was a fault in the program for locations other than North Carolina, and that fault brought lots of mail from those interested in using the program but mystified as to why it would crash at the 180-degree computation of their latitude/longitude.

Several Alaskan hams, particularly AL7HU, discovered a problem in the computation of the longitude at zero bearing in that northern latitude, and others (WA1WPJ, VK1BGG, and Glenn Skaggs of the Naval Research Laboratories in Washington, DC) explained an apparent anomaly at certain MUF computations in southerly directions.

The main problem was the syntax error that occurs when you try to compute the latitude and longitude at the 180-degree bearing. I knew that the equations don't permit computations along the line of equal longitude, and therefore included an IF statement to make the 180-degree bearing "your home longitude + .1". That statement was useless. Interestingly enough, however, the problem doesn't occur for all latitude/longitude computations. The quick fix was to insert two additional lines:

105 IF H = 180 THEN H = 182
106 IF H = 192 THEN H = 190

While that addition made the program work, the cause of the problem was still in question.

I added a temporary line to the program asking for the printout of the "Y" computation of **line 180** (see **table 1** of the original article). The test was done using the latitude/longitude for Lodi, California, the QTH of WA6FKM, one of several readers having trouble with the program.

As the bearing approaches 180 degrees, the computation for Y approaches 1. At 180 degrees the value of Y is 1.00000599. The next line, **190**, computes the longitude and has a term using 1-Y*Y. When Y is greater than 1, a negative term results and the computer can't take the square root of a negative number, so that produces the syntax error. A better way of handling the problem is to delete **lines 105** and **106** and insert the following statement instead.

185 IF ABS(Y) = > 1-1E-9 THEN Y = .999999

This will *always* work! If **line 185** is added, then **lines 105**, **106**, and **205** through **207** may be omitted.

The problem occurring at the high latitudes is that the zero-bearing 4000-km distance from Anchorage, Alaska, for example, is over the North Pole and down on the other side of the world. An IF statement at **line 200** says:

IF H = 0 THEN PRINT # . . . "HOME LONG. + .1"

Thus, the actual distance by a calculator is 2161 km. When I eliminated the **HOME LONG. + .1** statement and let the computer do its own thing, I discovered that it computed and printed the correct answer. So **lines 199** through **201** should be deleted.

The anomaly of the lower MUFs at certain southern bearings was explained by the fact that the MINIMUF program goes into a two-hop mode at ranges slightly greater than 4000 km. In my program

By Henry Elwell, N4UH, Route 2, Box 20G, Cleveland, North Carolina 27013

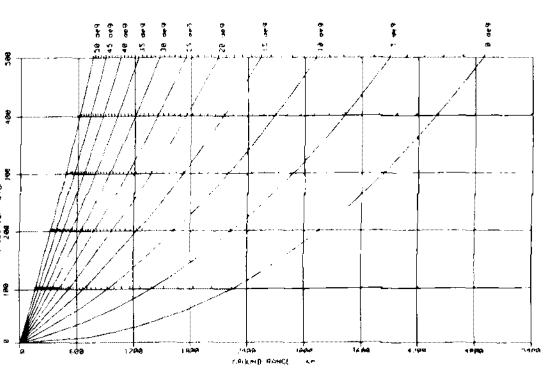


fig. 1. One-hop takeoff angle versus range and height.

it's attributable to a lack of precision (only one decimal point) in the results of the latitude/longitude program generation of the 4000-km periphery. Also, the 4000-km periphery for the first hop isn't practical for all stations because it's based on a vertical propagation angle of about 5 degrees or less. It's very practical for those with antennas producing such low angles of vertical radiation.

However, the average ham with, say, a tribander at 60 feet, has a takeoff angle of about 12 degrees on 20 meters. Thus a first-hop distance would be no more than 3000 km, depending upon the reflection height of the ionosphere. **Figure 1** shows the relation of one-hop takeoff angles vs. range and ionosphere height. Using the 3000-km first-hop great circle periphery requires substituting the following lines for **lines 110** and **180**:

110 L2 = .0022617638*cos(L1*.01745) *cos(H*.01745) + (-.9999974422)*sin(L1*.01745)
180 Y = (-.9999974422)-(sinL1*.01745* [same as original to its end]

Any other distance may be used and the sin and cos values of D/60 substituted, but remember that D is in nautical miles and is found from kilometers by dividing the km by 1.852. Of course, if you want to reach way out, leave the 4000-km computation as is.

combining programs

In my original article I said that it should be easy to combine the point-to-point prediction with the 360-degree prediction because both methods employ the basic MINIMUF program. Because I'd found that at times I wanted to know the 24-hour prediction from North Carolina to somewhere else while I was still in the 360-degree program, I went ahead and combined the two.

One of the first steps was to combine the latitude/longitude program with the main program; with only 10 to 11 lines required, it was an obvious thing to do. I often felt the need to use a different transmitter location than the one built into the program as DATA, and it was a nuisance to write it in for different locations all the time.

The new program permits the user to select any first-hop distance. The program then sets up a latitude array and a longitude array, both of which are tied in with the bearing (heading). It's interesting to see how the MUF retreats as you decrease the length of the first hop to less than 4000 km. You can see how a range of 900 km, for example, would restrict you to the 40-meter band or lower if there were no other layers, because the F2 layer doesn't support higher frequency transmissions for those distances under all circumstances. *Note that the MINIMUF program is based only on the F2 layer.*

This would be a good place to mention some of the factors upon which the MINIMUF program is based, as detailed in the technical report (TR-186) referenced by K6GKU in his article in *QST*,[2] which Glenn Skaggs duplicated and sent to me.

The MUF is principally controlled by the critical frequency of the F2 layer of the ionosphere. The critical frequency is that frequency which will be reflected from the ionosphere when a signal is transmitted vertically. Unlike propagation from the E and F1 layers, which can be modeled as a function of the angle of the sun from the zenith, F2 propagation prediction is more complex. The F2 layer has diurnal (day/night), seasonal, and geographical variations. It also has so-called anomalies: the MUF can be higher in midday in winter than in summer, although in the Northern Hemisphere the summer sun is further north and suggests higher ionization; also, the MUF can peak in the late afternoon rather than at midday on certain days.

Figure 2 shows the E-layer 2000-km MUF in megacycles for a particular day. The horizontal scale is local time, and the vertical scale is latitude. Note that for your latitude, the MUF starts out very low, peaks at noontime, and decreases as the day continues. Thus, you can predict E-layer MUF by the angle of the sun from its zenith. TR-186 says let's start from there, using the zenith angle as a forcing function to "drive" a semi-empirical model; we'll use a single-lag linear system such as an RC circuit as the model. Allowing the lag time constant to be long (about ten hours in the summer) and short (one hour in winter) at middle and equatorial latitudes, one could then at least partially reproduce both the seasonal and diurnal anomalies. The lag time constant during the day is a function of the midday solar zenith angle. The time constant at night is two hours, regardless of season or geographical location.

All this adds up to an equation which the authors of the article called the ionosphere as foF2:

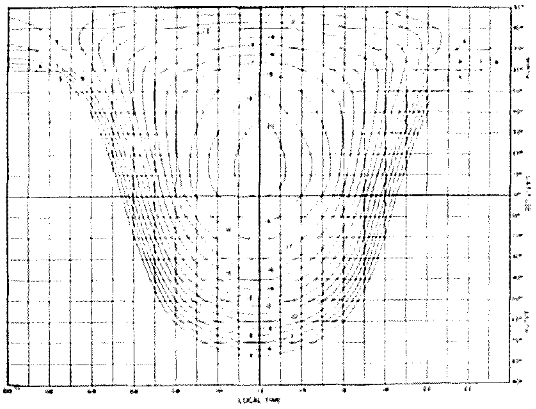


fig. 2. E-layer, 2000 MUF (predicted for June, 1947).

$$f_oF2 = \left[(1 + R/R_0) \sqrt{A_0 + A_1 (\sqrt{\cos X_{eff}})} \right]$$

where: R = sunspot number, $\cos X_{eff}$ is the cos of the effective solar zenith angle, and Ro, Ao and A1 are constants independent of geographic location and time.

Of course the technical report includes pages of equations for calculating those seemingly simple symbols which consider sunsets, sunrise, relaxation time, daytime duration, calculations of local noon, sunrise and sunset times, and the noon value of the solar zenith angle. Then we have to compute control points and two-hop paths if a 4000-km distance is exceeded. There's an M-factor that considers the ionosphere height of 290 km (which must change from winter to summer) and includes a factor for transequatorial paths, which increases MUF, a factor regarding increases in F2 layer heights observed at high northern latitudes during the summer, and others.

I chose MINIMUF 3.5 for the 360-degree propagation prediction because compared with advanced programs of its kind, it's very simple. I recommend that those who have more advanced prediction programs substitute them for MICROMUF 3.5. The subroutine for the MICROMUF program goes from **line 1140** to **2060**. When I first considered doing this revision, I thought a complete renumbering of the program would be neater and more desirable; however, recalling previous efforts, I decided to leave the numbering as it appeared in the orginal article for the benefit of others who may want to update their copies of the program.

I've eliminated a lot of unnecessary material in the new program. It starts out with a menu that asks whether you want a 360-degree or a point-to-point pre-

HOUR = 10Z DAY = 6 MONTH = JUN SF = 74
35.75 DEG 80.75 DEG 1ST HOP = 4000 KM

BEARING	MUF	BEARING	MUF
0	14.9	180	11.1
10	15.4	190	11.1
20	15.5	200	11.2
30	15.6	210	11.3
40	15.2	220	11.5
50*	14.7	230	11.7
60	17.7	240	11.9
70	17.0	250	12.1
80	16.3	260	12.3
90	15.6	270	12.6
100	14.9	280	12.8
110	14.3	290	13.2
120	13.7	300	13.7
130	13.1	310	11.5
140	12.5	320	12
150	11.9	330	13
160	11.2	340	14.5
170	11.1	350	14.5

PRESS P PRINT:Q QUIT:T TRY AGAIN

DATE:DAY 6 MONTH JUN
TRANSMITTER LOCATION:
LATITUDE 35.75 LONGITUDE 80.75
RECEIVER LOCATION:
LATITUDE 52 LONGITUDE 1
DISTANCE = 6298 KM
SUNSPOT NUMBER = 13

HOUR	MUF	HOUR	MUF
0	15.5	12	16.1
1	14.4	13	16.8
2	13	14	17.5
3	11.8	15	18
4	11.7	16	18.4
5	11.7	17	18.7
6	11.1	18	18.5
7	11	19	18.3
8	11	20	18
9	12.7	21	17.6
10*	14	22	17.1
11	15.1	23	16.4

PRESS P PRINT: Q QUIT: T TRY AGAIN

*Note: the approximate 50-degree 1000 UTC MUF is slightly higher as a one-hop prediction than the 1000 UTC MUF to England because of the greater number of hops needed.

fig. 3. Compare (A), the 360-degree propagation values, to (B), the predicted point-to-point conditions to England over the same period of time as shown in (A).

diction. It also displays a note stating that MUFs will be lower if the WWV K-factor is greater than 1. Most predictions, including MINIMUF, ignore the geomagnetic field activity (K > 1).

If you select a 360-degree prediction, you're asked whether you want your home coordinates. If so, you get them — provided, of course, that you've put them into **line 41**; mine are there now. If you want some other QTH, you're asked for that latitude and longitude; this is a good feature because you may want to see what's happening somewhere else or give information to a friend. Of course, you're also asked for the month, day, solar flux number, and the hour.

Once these decisions are made, the latitude/longitude computation takes place and is stored in memory to be used if you want to make other runs. It takes about 30 seconds for the computer to set up the information, but the screen tells you to wait. The screen also tells you to turn up the volume control of the monitor so you can be alerted by an automatic tone when the prediction is completed. You may then exit the program, run it again, or select a printout. If you want a prediction for another QTH, you must exit and start the program again so the new coordinates can be computed.

If you select the point-to-point prediction mode, you have similar decisions to make and enter into the computer as it requests them. There's also a tone to indicate completion of the prediction, but no notice of it beforehand, as in the 360-degree prediction.

In projects such as this, you reach the point at which you have to say "Enough!" and leave further development up to users; such is the case of a polar coordinate display, which is much more realistic than the same data presented in tabular form. WA1WPJ has devised a nice polar display for the C-128 and has offered to correspond with others who'd like more information; I appreciate his willingness to share his talents.

Figure 3 shows a comparison of the two printouts. The point-to-point prediction is from North Carolina to England, which has a bearing of approximately 50 degrees. Compare the two printouts for a time of 10Z, the time used for the 360-degree prediction, and you'll see that the one-hop MUF of the 360-degree prediction is 14.7 MHz, while the point-to-point prediction is 14 MHz. This difference is attributable to the fact that a two-hop mode is being used in the prediction, which lowers the MUF slightly when distances greater than 4000 km are used.

For those who wish to substitute another prediction in place of the MINIMUF 3.5 **lines 1140** to **2060**, an entrance and exit line has been inserted to change the transmitter latitude/longitude to radians and then back to degrees to facilitate printing degrees on the screen. There's also a short subroutine (**lines 2640** to

fig. 4. N4UH program provides MINIMUF 3.5 propagation predictions for any hour and point-to-point predictions for 24-hour periods.

```
1 REM THIS PROGRAM PROVIDES A MINIMUF PROPAGATION PREDICTION FOR 360 DEGREES
2 REM FOR A SPECIFIED TIME FROM 0 TO 23 HOURS GMT AS WELL AS A PT-TO-PT PRED.
4 REM IT HAS BEEN MODIFIED BY HENRY ELWELL N4UH TO DO THAT FROM AN EARLIER
5 REM PROGRAM BY ALAN MEMLEY, KE6UY
6 REM THE REVISED PROGRAM IS DATED 20 MAY 1987
10 PRINT CHR$(147)
11 A$=CHR$(17):REM CURSOR DOWN
12 B$=CHR$(18):REM REVERSE ON
13 C$=CHR$(19):REM HOME
14 D$=CHR$(29):REM CURSOR RIGHT
15 E$=CHR$(145):REM CURSOR UP
16 F$=CHR$(147):PRINTF$:REM CLEAR/HOME
17 G$=CHR$(158):PRINTG$:REM CONTROL-YELLOW
18 H$="****************************************"
19 QC=0:QD=0:OG=0:G=0:REM SEE LINE 4000 FOR EXPLANATION
20 DIMM$(37),A$(4),M(12),H(40),L2(360),W2(360)
21 DATA31,28,31,30,31,30,31,31,30,31,30,31
22 FORX=1TO12:READM(X):NEXT
23 M$="JANFEBMARAPRMAYJUNJULAUGSEPOCTNOVDEC"
24 PRINTA$A$H$
25 PRINT"*  THIS PROGRAM USES MINIMUF 3.5 FOR   *"
26 PRINT"*  TWO PROPAGATION PREDICTIONS:        *"
27 PRINT"*       1.FOR 360 DEGREES ANY GIVEN HOUR *"
28 PRINT"*       2.FOR POINT-TO-POINT FOR 24 HOURS*"
29 PRINT"* SELECT EITHER MODE BY PRESSING 1 OR 2*"
30 PRINTA$H$A$A$"NOTE:MUF WILL BE LOWER AS WWV K INDEX EXCEEDS 1"
31 GETI$:IF I$="" THEN 31
32 IF I$="2" THEN QC=1:GOTO35
33 IF I$="1" THEN GOTO35
34 GOTO 31
35 :
36 PRINTA$A$"USE HOME LAT/LONG (Y/N)?":I$
37 GETI$:IF I$ = "" THEN 37
38 IF I$<> "Y" THEN GOTO50
40 QD = 1 :REM USING HOME LAT/LONG
41 L1= 35.75: W1 = 80.75
50 :
200 POKE 53280,14
210 POKE 53281,6
230 PRINT F$
285 PI = 3.14159265
290 RO=PI/180
300 P1=2*PI
310 R1=180/PI
320 PO=PI/2
330 PRINT F$
337 IF QD = 1 THEN 343
340 PRINTA$:INPUT"WHAT IS THE TX LATITUDE":L1
342 PRINTA$:INPUT"WHAT IS THE TX LONGITUDE":W1
343 PRINT:INPUT"DATE (DAY,MONTH):":D6,MO
344 IFMO<=12THEN370
350 PRINT "INVALID MONTH. MUST BE IN RANGE 1-12"
360 GOTO343
370 IFM(MO)-D6<0THEN390
375 J$=MID$(M$,3*MO-2,3):REM PROVIDES A 3-LETTER ABBREVIATION FOR MONTH
380 GOTO410
390 PRINT "INVALID DAY"
400 GOTO343
410 PRINT:INPUT"SOLAR FLUX NUMBER:":SF
420 IFSF<70THENPRINT"DO NOT USE SF < 70":GOTO410
425 IF QC=1 THEN GOTO600:REM QC USED FOR PT-TO-PT. PREDICTION
428 IFOG=1THEN GOTO450
430 PRINTA$:INPUT"GIVE DISTANCE TO 1ST HOP IN KM":K
440 NA=K/1.852: REM CONVERTS FROM KM TO NAUTICLA MILES
450 PRINT:INPUT"WHAT GMT DESIRED: 0-23 HOURS ONLY ":TG
460 IFTG>23THENPRINT"USE HOURS 0 TO 23 ONLY":GOTO450
470 IFOG=1 THEN GOTO540
480 PRINT:PRINT"TURN UP AUDIO GAIN TO HEAR END OF RUN     SIGNAL"
490 PRINT"THERE IS A 30 SECOND WAIT WHILE"
495 PRINT"COMPILING THE"K   "KM LAT/LONG INFO"
500 FOR H=0TO350 STEP 10
504 V=SIN((NA/60)*RO)*COS(L1*RO)*COS(H*RO)+COS((NA/60)*RO)*SIN(L1*RO)
508 L2=ATN(V/SQR(1-V*V))*57.2957795: REM LAT. OF DISTANT POINT
510 L2(H)=L2:REM ARRAY FOR 4000 KM LATITUDE CIRCUMFERENCE
512 O=(COS((NA/60)*RO)-(SIN(L1*RO)*SIN(L2(H)*RO)))/(COS(L1*RO)*COS(L2(H)*RO))
514 IF ABS(O)=>1-1E-9 THEN O = .999999
516 W2=(PI/2-ATN(O/SQR(1-O*O)))*57.296: REM S IS THE ARCOS CONVERSION TO DEGREES
518 IF H=<180 THENW2=-(W2-W1)
520 IF H> 180 THEN W2=W2+W1
522 W2(H)=W2:REM ARRAY FOR 4000 KM LONGITUDE CIRCUMFERENCE
524 NEXT H
540 S9=(SQR(.52998-.00356*(63.75-SF))-.728)/.00178
550 S9=INT(S9):REM SUNSPOT NUMBER
552 IF QC=1 THEN GOSUB2640
555 IFQC=1 THEN 700
560 FOR H=0 TO 350 STEP 10
570 IFG=1 GOTO950
580 PRINTF$:PRINT A$"HOUR="TG"Z DAY="D6"MONTH= "J$" SF="SF
```

```
585 PRINTL1"DEG";W1"DEG";" 1ST HOP=";K"KM"
590 PRINTTAB(4)"BEARING";TAB(15)"MUF";TAB(21)"BEARING";TAB(33)"MUF"
595 GOTO 950
600 PRINTA$:INPUT"RECEIVER LAT. LONG";L2,W2
602 IF L<-90 THEN 608
604 IF L2>90 THEN 608
606 GOTO 614
608 PRINT"INVALID LATITUDE. MUST BE IN RANGE"
610 PRINT"OF -90 TO 90 DEGREES"
612 GOTO 600
614 IF W2 < -360 THEN 620
616 IF W2> 360 THEN 620    .
618 GOTO540
620 PRINT"INVALID LONGITUDE. MUST BE IN RANGE -360 TO 360"
622 GOTO 600
700 PRINTF$A$:"DATE:":"DAY"D6 ;"MONTH "J$
710 PRINT"  TRANSMITTER LOCATION:"
720 PRINTTAB(7)"LATITUDE";L1;TAB(22):"LONGITUDE";W1
730 PRINT"  RECEIVER LOCATION:"
740 PRINTTAB(7)"LATITUDE";L2;TAB(22):"LONGITUDE";W2
750 PRINT"  DISTANCE ="DX;"KM"
760 PRINT"  SUNSPOT NUMBER = ";S9
770 PRINT
780 PRINTTAB(4)"HOUR";TAB(11)"MUF";TAB(21)"HOUR";TAB(28)"MUF
945 IF QC=1 THEN GOTO 955
950 T5=TG:GOTO 970 :REM HOLDS TIME CONSTANT FOR 360' PREDICTION
955 FOR T5= 0 TO 24
960 IF T5>23 THENGOSUB3050:GOTO 2950
970 GOSUB1140
980 J9=J9*10
990 J9=INT(J9)
1000 J9=J9/10
1005 PRINTE$
1010 IFQC=1ANDT5=12THENE=12:FORI=1TOE:PRINTE$;:NEXTI:PRINTTAB(21)T5;TAB(27)J9:NE
XTT5
1015 IFQC=1 AND T5> 12 THEN PRINT TAB(21)T5;TAB(27) J9:NEXT T5
1020 PRINTE$:IFQC=1 THEN PRINTTAB(4)T5;TAB(10)J9:NEXT T5
1021 IFH=180THENE=18:FORI=1TOE:PRINTE$;:NEXTI:PRINTTAB(22)H;TAB(32)J9:NEXTH
1022 IFH>180THENPRINT TAB(22)H;TAB(32)J9:NEXT H
1023 IFH=360 THENGOTO1040
1030 PRINT   TAB(4)H;TAB(13)J9
1040 IFH=360THEN GOSUB3050:PRINTB$"PRESS P-PRINT:Q-QUIT:T-TRY AGAIN":GOTO3000
1041 NEXT H
1049 IF QC=1 THENPRINTE$E$:PRINTTAB(21)T5;TAB(27)J9:GOTO1060
1050 PRINTE$E$:PRINTTAB(21)H:TAB(27)J9
1060 :
1065 NEXT H
1140 REM MINIMUF 3.5
1141 L1=L1*RO:W1=W1*RO
1145 IFQC=1THEN K7=SIN(L1)*SIN(L2*RO)+COS(L1)*COS(L2*RO)*COS(W2*RO-W1):GOTO1160
1150 K7=SIN(L1)*SIN(L2(H)*RO)+COS(L1)*COS(L2(H)*RO)*COS(W2(H)*RO-W1)
1160 IFK7=>-1THEN1190[redacted]"
1170 K7=-1
1180 GOTO1210
1190 IFK7<=1THEN1210
1200 K7=1
1210 G1=-ATN(K7/SQR(-K7*K7+1))+PI/2
1220 K6=1.59*G1
1230 IFK6>=1THEN1250
1240 K6=1
1250 K5=1/K6
1260 J9=100
1270 FORK1=1/(2*K6)TO1-1/(2*K6)STEP0.9999-1/K6
1280 IFK5=1THEN1295
1290 K5=0.5  `
1295 IF QC=1 THEN P=SIN(L2*RO):GOTO1305
1300 P=SIN(L2(H)*RO)
1305 IF QC=1 THEN Q=COS(L2*RO):GOTO1320
1310 Q=COS(L2(H)*RO)
1320 A=(SIN(L1)-P*COS(G1))/(Q*SIN(G1))
1330 B=G1*K1
1340 C=P*COS(B)+Q*SIN(B)*A
1350 D=(COS(B)-C*P)/(Q*SQR(1-C^2))
1360 IFD>=-1THEN1390
1370 D=-1
1380 GOTO1410
1390 IFD<=1THEN1410
1400 D=1
1410 D=-ATN(D/SQR(-D*D+1))+PI/2
1415 IF QC=1THEN WO=W2*RO+SGN(SIN(W1-W2*RO))*D:GOTO1430
1420 WO=W2(H)*RO+SGN(SIN(W1-W2(H)*RO))*D
1430 IFWO=>0THEN1450
1440 WO=WO+P1
1450 IFWO<P1THEN1470
1460 WO=WO-P1
1470 IFC=>-1THEN1500
1480 C=-1
1490 GOTO1520
1500 IFC<=1THEN1520
1510 C=1
1520 LO=PO-(-ATN(C/SQR(-C*C+1))+PI/2)
1530 Y1=0.0172*(10+(MO-1)*30.4+D6)
1540 Y2=0.409*COS(Y1)
```

```
1550 K8=3.82*W0+12+0.13*(SIN(Y1)+1.2*SIN(2*Y1))
1560 K8=K8-12*(1+SGN(K8-24))*SGN(ABS(K8-24))
1570 IFCOS(LO+Y2)>-0.26THEN1660
1580 K9=0
1590 G0=0
1600 M9=2.5*G1*K5
1610 IFM9<=POTHEN1630
1620 M9=PO
1630 M9=SIN(M9)
1640 M9=1+2.5*M9*SQR(M9)
1650 GOTO1910
1660 K9=(-0.26+SIN(Y2)*SIN(LO))/(COS(Y2)*COS(LO)+1.0E-3)
1670 K9=12-ATN(K9/SQR(ABS(1-K9*K9)))*7.639437
1680 T=K8-K9/2+12*(1-SGN(K8-K9/2))*SGN(ABS(K8-K9/2))
1690 T4=K8+K9/2-12*(1+SGN(K8+K9/2-24))*SGN(ABS(K8+K9/2-241)
1700 CO=ABS(COS(LO+Y2))
1710 T9=9.7*CO^9.6
1720 IFT9>0.1THEN1740
1730 T9=0.1
1740 M9=2.5*G1*K5
1750 IFM9<=POTHEN1770
1760 M9=PO
1770 M9=SIN(M9)
1780 M9=1+2.5*M9*SQR(M9)
1790 IFT4<TTHEN1820
1800 IF(T5-T)*(T4-T5)>0THEN1830
1810 GOTO1960
1820 IF(T5-T4)*(T-T5)>0THEN1960
1830 T6=T5+12*(1+SGN(T-T5))*SGN(ABS(T-T5))
1840 G9=PI*(T6-T)/K9
1850 G8=PI*T9/K9
1860 U=(T-T6)/T9
1870 G0=CO*(SIN(G9)+G8*(EXP(U)-COS(G9)))/(1+G8*G8)
1880 G7=CO*(G8*(EXP(-K9/T9)+1))*EXP((K9-24)/2)/(1+G8*G8)
1890 IFG0=>G7THEN1910
1900 G0=G7
1910 G2=(1+S9/250)*M9*SQR(6+58*SQR(G01)
1920 G2=G2*(1-0.1*EXP((K9-24)/3))
1930 G2=G2*(1+(1-SGN(L1)*SGN(L2))*0.1)
1940 G2=G2*(1-0.1*(1+SGN(ABS(SIN(LO))-COS(LO))))
1950 GOTO2020
1960 T6=T5+12*(1+SGN(T4-T5))*SGN(ABS(T4-T5))
1970 G8=PI*T9/K9
1980 U=(T4-T6)/2
1990 U1=-K9/T9
2000 G0=CO*(G8*(EXP(U1)+1))*EXP(U)/(1+G8*G8)
2010 GOTO1910
2020 IFG2>J9THEN2040
2030 J9=G2
2040 NEXTK1
2050 J9=.93*J9
2060 G=1:L1=L1*R1:W1=W1*R1:RETURN
2640 DY=SIN(L1*RO)*SIN(L2*RO)+COS(L1*RO)*COS(L2*RO)*COS(W1*RO-W2*RO)
2650 DX=60*(PO-ATN(DY/SQR(1-DY*DY)))*57.296:REM DISTANCE IN NAUTICAL MILES
2670 DX=DX*1.852:REM CONVERTS FROM NAUTICAL MILES TO KM
2680 DX=INT(DX):RETURN
2950 PRINTB*A$"PRESS P-PRINT:Q-QUIT:T-TRY AGAIN
3000 GETAN$:IFAN$=""THEN3000
3010 IFAN$="P"GOTO3200
3020 IFAN$="Q"THENPRINTF$A$A$D$D$D$"ENJOY YOUR RADIO!":END
3030 IFAN$="T"THEN PRINTF$:OG=1:G=0:GOTO343
3035 GOTO3000
3050 : REM TONE TO TELL WHEN SCREEN PRINT COMPLETE
3052 FOR AC=54272TO54296:POKEAC,0:NEXT
3054 POKE54296,15
3056 POKE54277,0
3058 POKE 54278,248
3060 POKE54273,35:POKE54272,134
3062 POKE54276,17
3064 FORT=1 TO 1000 :NEXT
3066 POKE54276,16:RETURN
3199 REM SCREEN DUMP
3200 OPEN3,3:OPEN4,4:PRINTC$:FORI=1TO1000:GET#3,A$:PRINT#4,A$;:NEXT:CLOSE3
3210 CLOSE4
3220 END
4000 REM QC= FLAG TO SELECT PREDICTION OPTION 2
4001 REM QD= FLAG SELECTS HOME LAT/LONG OF LINE 41
4002 REM OG= FLAG TO SKIP 1ST HOP COORDINATES FOR THE "TRY AGAIN"
4003 REM G= FLAG SKIPS REPRINTING 360 DEGREE TABLE TITLE
60000 OPEN15,8,15,"S0:360/PTP MUF":CLOSE15:SAVE"0:360/PTP MUF",8

READY.
```

2680) for computing the distance between the transmitter and receiver for the point-to-point prediction. That distance, used only for information to the screen, replaces several lines in the original program which had not been used.

The equation for S9, the sunspot number in **line 540**, has been changed in response to a suggestion from Glenn Skaggs. The original equation produces sunspot numbers slightly low at low flux numbers and slightly high at high flux numbers. The new equation gives a closer fit when converting flux to sunspot number.

The original article generated letters asking if I would copy the program to readers' disks. If you'll send me a disk with return postage (or a dollar bill if that's easier), I'll copy the program shown in **fig. 4** to your disk and return it.

acknowledgments

Besides those already mentioned herein, I want to thank Bob Brown, NA7M, for educating me about the more advanced programs he enjoys.

references

1. Henry G. Elwell, Jr., N4UH, "360-degree MINIMUF Propagation Prediction," *ham radio*, February, 1987, page 25.
2. Robert B. Rose, K6GKU, "MINIMUF: A Simplified MUF-prediction Program for Microcomputers," *QST*, December, 1982, page 36.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

try an oscilloscope for troubleshooting dc power supplies

It is something of a truism that the first place to look for trouble in a piece of malfunctioning electronic equipment is the dc power supply. Almost everyone who keeps records of equipment failure will report that a large percentage of repair actions involve the low-voltage dc power supply. This problem is so commonplace, and such a logistics cost driver, that the United States Navy now has a power supply standard that, among other things, limits the maximum junction temperature of semiconductor devices to 110 degrees C, and also limits the power-per-unit-of-volume (watts/cubic inch).

The typical low-voltage dc power supply will have a transformer to step down the 120-VAC line voltage to some lower voltage. The exact value of the transformer secondary voltage, of course, depends upon the dc output potential of the supply. The output of the transformer will be a sine wave or near-sine wave (**fig. 1A**). The transformer voltage ratings sometimes yield some confusing results for the troubleshooter. For example, let's consider the standard 12.6-VAC transformer (**fig. 1B**). The rated voltage of a transformer is the RMS potential across the entire secondary, unless otherwise specified.

If you use a reasonably good quality ac voltmeter, the reading will be 12.6-VAC across points A-B — right?

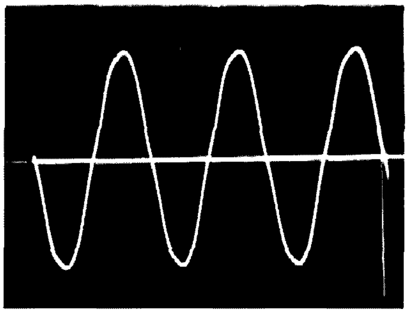


fig. 1A. Output of a typical low-voltage dc power supply transformer is a sine wave or near-sine wave.

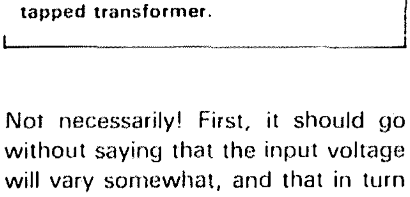


fig. 1B. Standard 12.6-VAC center-tapped transformer.

Not necessarily! First, it should go without saying that the input voltage will vary somewhat, and that in turn reflects variation in the secondary voltage. Measurements I made in preparation of this article showed a line voltage of 123-VAC RMS at my QTH, while at other times it has been as low as 102-VAC RMS.

Second, the rated voltage of a transformer assumes a minimum load current being drawn. If you measure a transformer with no load, you can expect a higher voltage than the rated potential. Some transformers are worse than others in this respect, but all will demonstrate this phenomenon to some extent. The problem lies in the internal resistance of the secondary windings. I've seen a 12.6-VAC @20-ampere transformer show a 22-VAC "RMS" on a digital ac voltmeter of good quality until a 500-mA load was placed across the secondary. The load reduced the secondary potential to 12.6-VAC RMS ± line fluctuation.

If the transformer is center-tapped, as in **fig. 1B**, then the rating of the secondary must be scrutinized to determine the actual voltage. For example, "12.6 VAC C.T." means that 12.6 VAC appears across A-B, while the potential readings from CT to A and CT to B will be 6.3-VAC RMS each.

Another point of confusion is found when measuring the voltage across the transformer secondary with an oscilloscope. Most ac meters are RMS-reading devices (or nearly so) for sine waves, unless they're specifically designed for peak-to-peak or peak-reading applications. But the oscilloscope is inherently a peak-to-peak reading instrument. In **fig. 1A**, the horizontal line denotes the zero-volts baseline, while the positive excursions are above the line and negative excursions are below the line (following the standard convention). The peak voltage is the potential between the zero baseline and either peak, while the

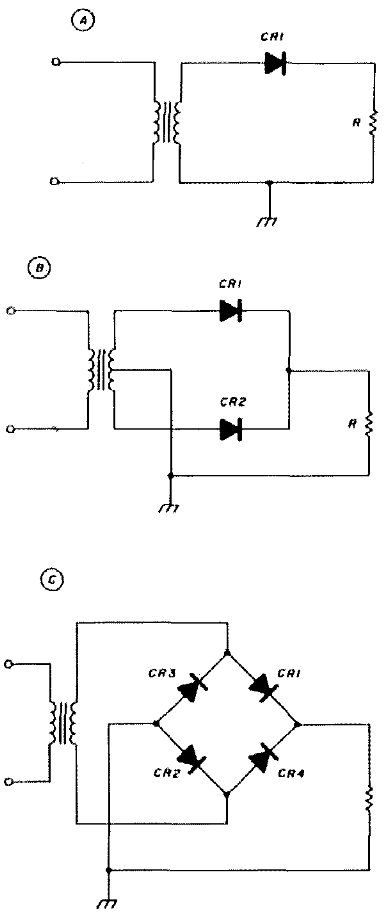


fig. 2. Forms of rectifiers: (A) half-wave; (B) conventional full-wave; (C) full-wave bridge.

peak-to-peak voltage is the reading between a negative peak and the adjacent positive peak. The peak voltage is 1.414 times RMS voltage, while the peak-to-peak voltage is 2.83 times the RMS voltage. On the oscilloscope and meter readings, we need to divide the peak-to-peak reading obtained on the oscilloscope by 2.83. Similarly, multiplying the RMS reading on the meter by 2.83 gives us the approximate peak-to-peak voltage to expect on the oscilloscope screen.

Because the ac voltage provided by the transformer is useless for most electronic circuits, we provide a rectifier to convert bipolar ac to unipolar pulsating dc. **Figure 2** shows the various forms of rectifiers, while **figs. 3A** and **3B** show the waveforms that the scope will show when connected across load resistor R. The device in **fig. 2A** is the half-wave rectifier, and it produces the waveform shown in **fig. 3A**. Note that only the positive half of the applied ac sine wave is applied, which causes a certain amount of inefficiency in this form of power supply. The other two rectifiers are both full-wave types, and they produce the waveform shown in **fig. 3B**. The rectifier shown in **fig. 2B** is a conventional full-wave rectifier, and depends upon the center-tap of the transformer secondary winding in order to provide a ground reference.

The rectifier in **fig. 2C** is a full-wave bridge. It does not require a center-tapped transformer, but instead uses a node of the bridge to provide the ground reference. This article is based on the bridge rectifier, by far the most commonly used rectifier in modern equipment. **Fig. 4** shows the circuit of the dc power supply that was used in making the measurements and waveform photographs. The transformer was an 8.5-VAC @1-ampere transformer, while the rectifiers (CR1-CR4) were 1N400x-series devices.

Figures 5A and **5B** show the normal waveform expected when the oscilloscope probe is applied to points A and B in **fig. 4**. Each waveform is half-wave rectified, but each is 180 degrees out of phase with the other. This phasing reflects the fact that the bridge rectifier is full-wave, and therefore uses the entire 360 degrees of the input ac waveform. Even with a single-trace oscilloscope, you can tell that the circuit

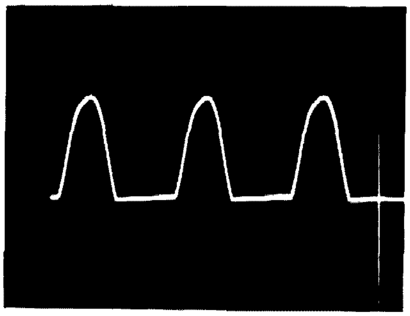


fig. 3A. Waveform produced by half-wave rectifiers.

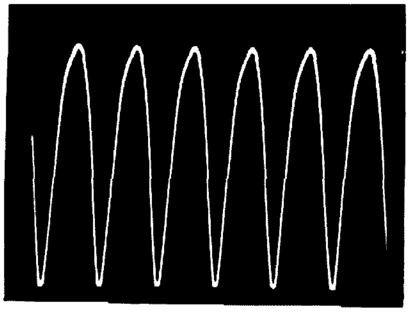


fig. 3B. Waveform produced by full-wave rectifiers.

is working correctly by the half-wave trace. **Figure 5B**, on the other hand, shows an anomaly. I once saw this waveform in a piece of equipment in which the printed circuit trace from the + terminal of the bridge rectifier was cracked, and that effectively removed the load from the rectifier. If you see a sine wave or near-sine wave at the ac nodes of the bridge (points A and B in **fig. 4**,) you should suspect that the load is somehow disconnected.

The full-wave pulsating dc wave-

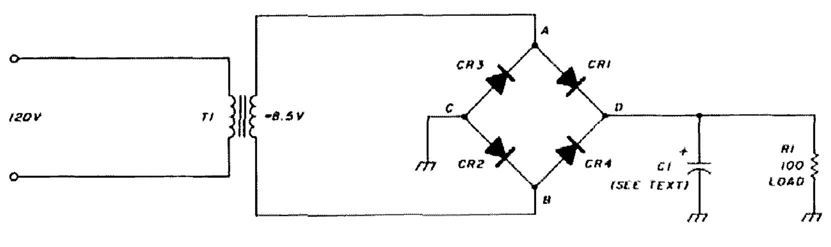


fig. 4. Circuit of low-voltage dc power supply used in making measurements and photographs for this article.

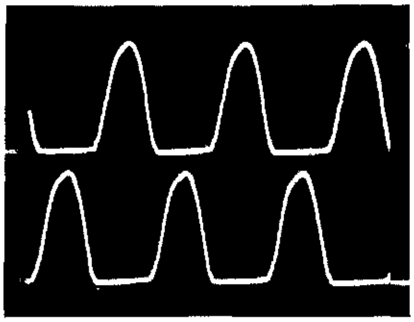


fig. 5A. Normal waveform generated when oscilloscope probe is applied to points A and B in fig. 4.

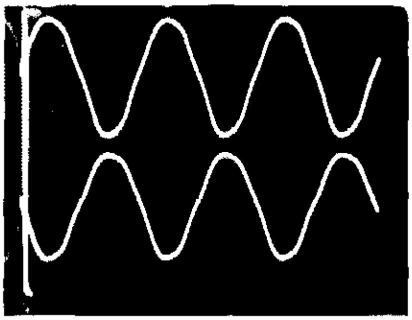


fig. 5B. Anomalous waveform indicates defective circuit.

form of fig. 3B is almost as useless for electronic equipment as ac, so circuit designers supply a filter capacitor such as C1 in fig. 4. Figure 6 shows two cases of a filtered pulsating dc output from the low-voltage power supply of fig. 4. In both figs. 6A and 6B the horizontal white line was placed at the zero-volts line in order to provide a frame of reference. The line was made by adjusting the position control for channel 2 of the oscilloscope, and keeping the input selector in the grounded position. The waveform of fig. 6A represents the case in which 500 μF of filter capacitance was used; in this situation, the digital voltmeter read 12.03 Vdc, while the measurements on the oscilloscope screen showed 10.8 volts between the zero-volts baseline and the bottom of the ripple waveform, and 12.4 volts to the peak of the ripple waveform (resulting in a ripple amplitude of 1.6 volts). In fig. 6B, the filter capacitor is increased to 2700 μF. The DVM read 12.01 Vdc,

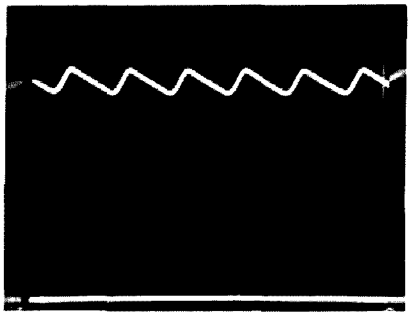


fig. 6A. Filtered pulsating dc output from the low-voltage power supply shown in fig. 4; 500 μF of filter capacitance results in ripple amplitude of 1.6 volts.

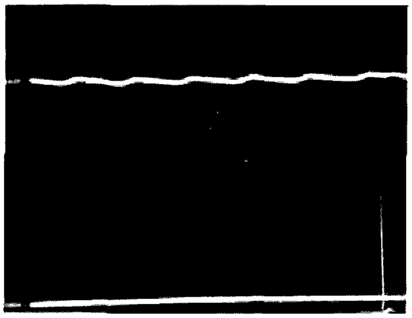


fig. 6B. With filter capacitance increased to 2700 μF, ripple amplitude drops to 0.25 volts.

while the oscilloscope showed 12.0 volts between zero and the bottom of the ripple waveform. The ripple amplitude in **fig. 6B** is 0.25 volts, or 15.6 percent of the case where 500 μF was used for the filter. Obviously, the greater the capacitance, the less the ripple. The general rule of thumb for the value of capacitance needed in a full-wave supply is:

$$C = \frac{1,000,000}{416 \cdot R_L \cdot RF}$$

where:

C is the capacitance in microfarads
R_L is the load resistance (Vo/Io)
RF is the required ripple factor

If the filter capacitor is open — a common fault — then you should expect to see the pulsating dc waveform of **fig. 3B** across the load resistor, instead of the distinctive waveforms of **fig. 6**. A certain amount of judgment and experience is needed, however, in the case where the filter capacitance is reduced significantly. This fault occurs occasionally in aluminum electrolytics, especially in equipment that has been unused for a while. Some service literature will show you the peak-to-peak readings to expect across the filters; in other cases, only experience or hunches will aid the troubleshooter.

Figures 7A and **7B** show a pair of ripple waveforms found in another situation. Both waveforms were made with the oscilloscope's vertical input ac-coupled because we are specifically looking at ripple, rather than at the ripple + dc component. The top waveform (**fig. 7A**) shows a filtered pulsating dc waveform in a normally operating dc power supply. In a full-wave rectified supply, the ripple frequency is twice the line frequency, or 120 Hz in the United States. But **fig.** 7B shows the same power supply with one leg of the bridge (CR4 of **fig. 4**) open-circuited. The ripple amplitude is up — a fact that could also be attributed to a weak filter capacitor — but the ripple frequency is one-half the expected frequency. On the oscilloscope timebase (horizontal) line, you'll find that the ripple waveform on a full-wave circuit will have a period of 1/120 Hz, or about 8.3 milliseconds. The half-wave rectified ripple waveform resulting when a diode is opened produced a period of 16.7 milliseconds on the oscilloscope.

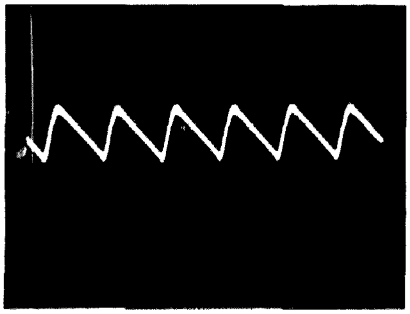


fig. 7A. Ripple waveform of filtered pulsating waveform in a dc power supply operating normally.

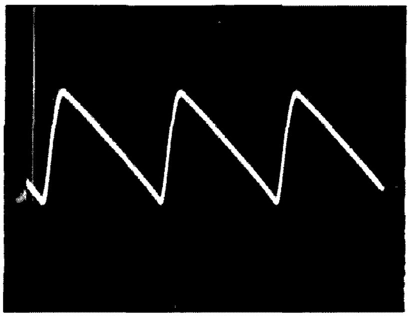


fig. 7B. Ripple waveform of power supply operating with one leg of the bridge open-circuited.

A lesson to be learned from this example is to examine not just the amplitude of the waveform, but also its period/frequency. Also, if its shape is wrong, then suspect a fault (again, examine the difference between **figs. 5A** and **5B**).

regulated power supplies

Most Amateur equipment uses voltage-regulated dc power supplies. This fact is due, in part, to the nature of modern solid-state circuits, which simply work better when the power supply is voltage regulated. It's also attributable in large part to the fact that IC voltage regulators are widely available today. In past times, because it was expensive to regulate supplies, many manufacturers used unregulated supplies. **Figure 8** shows a basic IC voltage regulator circuit based on the three-terminal IC regulator devices. In making the measurements for this article I used a 7805 device, which — for our purposes — is the same as the LM-309 and LM-340T-05 devices, all of which produce 5 volts output for TTL digital circuits. Similar devices are available in output voltages to 24 Vdc, both positive and negative.

One effect of the voltage regulator is to greatly reduce the ripple of the power supply. In fact, in 1964 a manufacturer of test equipment marketing a new regulated bench supply (then a rarity) bragged that it had the "equivalent of 1 Farad of filtering." The voltage regulator produced a reduction in ripple equivalent to what would be obtained with 1,000,000 μF of filter capacitance! This effect is shown in **fig. 9**. The upper trace, A, is taken at point "A" in **fig. 8**, and represents the

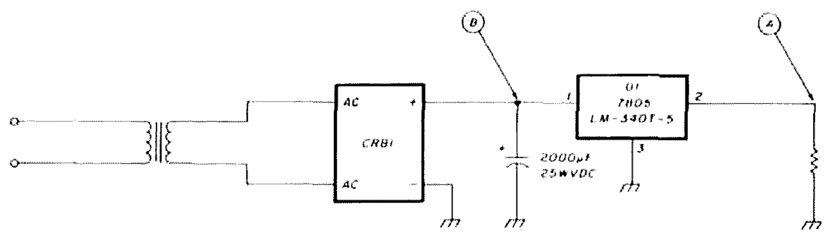


fig. 8. Basic IC voltage regulator circuit.

output waveform from the regulator. The bottom trace is the filtered pulsating dc at the input of the regulator device (point "B" in **fig. 8**). Both trace photos were taken with the oscilloscope's vertical attenuator set to 0.1 volts/cm. The bottom trace shows 160 mV of ripple, while the upper trace shows no discernible ripple. In fact, the oscilloscope showed no discernible ripple on all settings of the attenuator except at the 5-mV/cm (most sensitive) position. A defective regulator will show a high ripple on the output as well as an incorrect voltage.

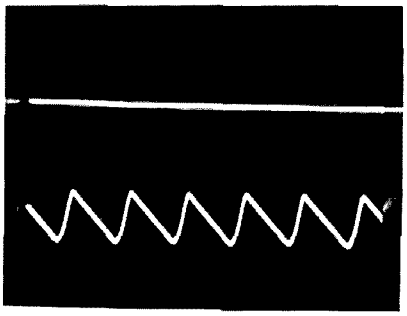


fig. 9. Voltage regulator greatly reduces ripple of power supply. Upper trace (A) was taken at point "A" in fig. 8; lower trace (B) is filtered pulsating dc at input of regulator (point "B" in fig. 8).

WARNING: Defective regulators can produce a higher than normal voltage at the output of the supply! That potential can damage electronic circuits, so immediately turn off the equipment if this result is found. If the regulator is a simple IC type, then it can be replaced and the circuit inspected for damage.

I use a current-limited bench power supply to troubleshoot equipment of this sort. Disconnect the regulator, set the bench output voltage to the same potential the regulator is supposed to produce, set the current-limiting control to the rated value produced by the regulator, and then connect the bench supply across the equipment circuits. If the circuits are undamaged, they will function correctly. Next, place a load resistor across the output of the regulator (the equipment circuits are still disconnected). It should draw a current of 25 to 100 percent the normal load for that particular supply. Measure the output voltage and examine the waveform across the load resistor. If the regulator is operating correctly, you may reconnect the circuits to the replaced or repaired regulator.

conclusion

Although professional servicers almost invariably prefer troubleshooting with oscilloscopes, many people still mistakenly believe that the dc voltmeter is the only instrument useful for troubleshooting dc supplies. In this article we've seen that the oscilloscope is also useful for this job — which strengthens my conviction that all technically inclined Amateurs ought to obtain good oscilloscopes for their workshops.

WARNING: *techniques presented in this article are for low-voltage dc power supplies only. Do not attempt to use them on a high-voltage supply unless a suitable high-voltage probe is provided. Otherwise, damage to the oscilloscope may result, and the high voltage present may also be dangerous to you.*

ham radio

pulse width modulated dc-to-dc converters

Get the voltage you want — and high efficiency, too

How many times have you required a voltage lower, higher, or of opposite polarity than that provided by your power supply or battery? If you wanted to draw 5 volts from a 15-volt source, for example, you could use a linear regulator or a zener diode — but with efficiency of only 33 percent or less. By using a dc-to-dc converter, however, you could obtain your desired voltage with an efficiency of 65 to 80 percent or more.

While a number of different types of dc-to-dc converter circuits can be used, this article deals exclusively with the pulse width modulated (PWM) type. A wide variety of PWM ICs are available from a number of suppliers such as National, RCA, Fairchild, Motorola, Silicon General, Unitrode and others.

buck or forward converter

The first type examined will be the buck or forward converter used to supply a voltage lower than the input. Referring to **fig. 1**, note that the basic buck converter consists of a switch (S), a diode, an inductor, a capacitor, and a load resistor. In a practical converter, the switch is replaced by a transistor or FET driven by pulses supplied from a PWM chip.

When the switch is closed, current starts to build up gradually as the inductor opposes a rapid change in current flow. The capacitor begins to charge, and an EMF appears across the load. As the current increases, a magnetic field builds up in and about the inductor. The switch then opens, and forward current flow ceases. At this point the magnetic field collapses, inducing a voltage in the inductor of opposite polarity.

The energy induced in the inductor flows through the diode to the capacitor and load. Energy is supplied to the load from that stored in the inductor. The ratio of the time on (switch closed) to time off (switch open) determines the total energy delivered to the load, and therefore the output voltage. The PWM chip will monitor the output via the feedback resistor in a practical circuit, compare it with the internal reference voltage of the chip, and precisely control the ratio of on time to off time to maintain a constant output voltage. As the load is increased, the on time increases; as the load is decreased, the on time decreases. This circuit can be used to obtain an output voltage lower than the input by at least 2 volts or more.

flyback converter

Figure 2 shows a basic flyback converter with the same five basic components arranged in a different manner. In this circuit, when the switch is closed, energy is stored in the inductor because it cannot flow to the capacitor and load because of the diode. When the switch is open, the energy stored in the inductor is transferred to the capacitor and load because the diode is now forward biased. With this circuit, you can obtain a supply of reverse polarity greater than, less than, or equal to the input voltage.

boost or step-up converter

Figure 3 illustrates a basic boost or step-up circuit. In this circuit, we see the same five components arranged differently. When the switch is closed, the inductor is connected in parallel with the input, and energy is once again stored in the inductor.

By William R. Hennigan, W3CZ, 975 Clopper Road, Apartment A2, Gaithersburg, Maryland 20878

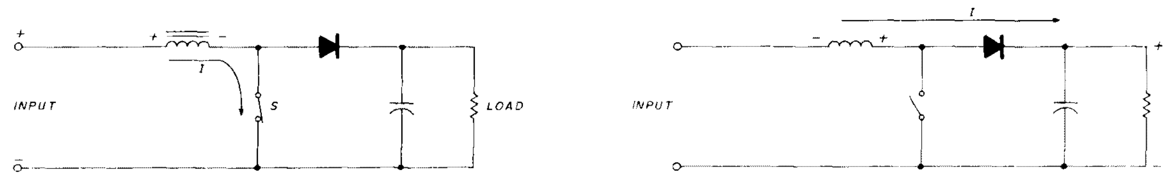


fig. 1. Buck or forward converter supplies an output voltage lower than its input — i.e., $E_{IN} > E_{OUT}$.

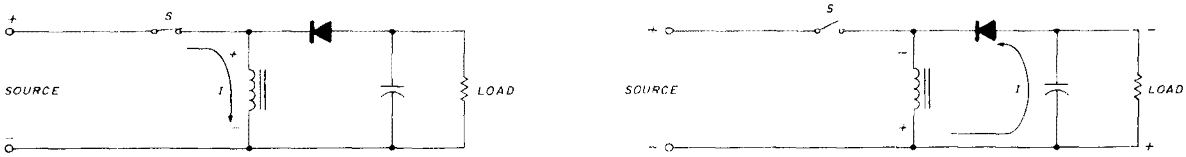


fig. 2. Flyback converter provides a reverse polarity output that *is* greater *than*, *equal* to, *or less than* the input voltage in magnitude.

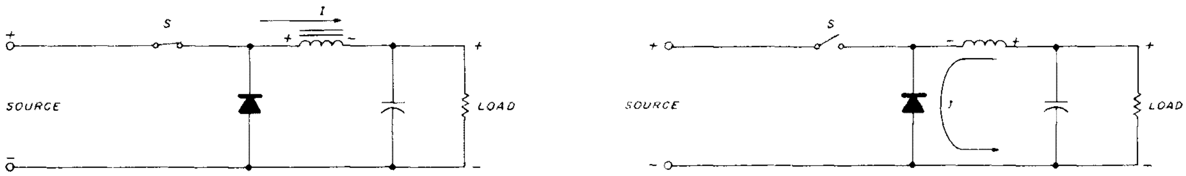


fig. 3. In this boost circuit the output is the sum of the input voltage and the voltage across inductor, i.e. $V_{OUT} > V_{IN}$.

When the switch is open, the energy in the inductor is transferred to the load and this voltage is now connected in series with the input; thus the output is the sum of the input voltage and the voltage across the inductor. This circuit can be used only as a step-up or boost circuit. It does suffer from one fault, however, which I'll explain later.

buck or step-down converter

A practical buck or step-down forward converter can be constructed using a 3524 IC, a chip that's readily available from a number of suppliers. **Figure** 4 shows a schematic of an 8-volt regulated supply with an input of 12 volts. I built this circuit several years ago; the 8-volt output was loaded from 150 to 500 mA with a measured efficiency that varied from 83 to 85 percent.

Note that the internal reference at pin 16 is divided down to 2.5 volts at pin 2. This is necessary because the comparator in the chip is powered off the 5-volt reference and has a common mode input of 1.8 to 3.4 volts (see **fig. 5** for the internal circuitry of the chip). The Unitrode UC1524 family of chips has a higher common mode input because the comparators are powered off the input voltage of the chip; if they're used in this circuit — with 12-volt input — the reference could be applied directly to pin 2 by means of a resistor. The current limit comparator (pins 4 and 5) also has the same common mode input limitations with the LM3524, so the current limit resistor is in the negative lead in the circuit shown. The resistor value of RCL can be tailored to fit the need. A 1-ohm resistor will current limit at about 200 mA, a 0.2-ohm resistor at about 1 ampere, and a 0.4-ohm resistor at about 500 mA. The current limit value is the value of a resistor whose voltage drop equals 0.2 volts. If current limiting isn't necessary, it can be omitted and the leads connected together at this point, forming a jumper between point A and B.

L1 and L3, wound on toroids, consist of 45 turns of No. 25 wire on Micrometals T68-26A cores. These plus C6 can also be omitted if the ripple from the supply at both the 12-volt input and 8-volt output is acceptable.

Any of the 1524, 2524, 3524 chips will operate in the circuit shown in **fig.** 4. The operating frequency

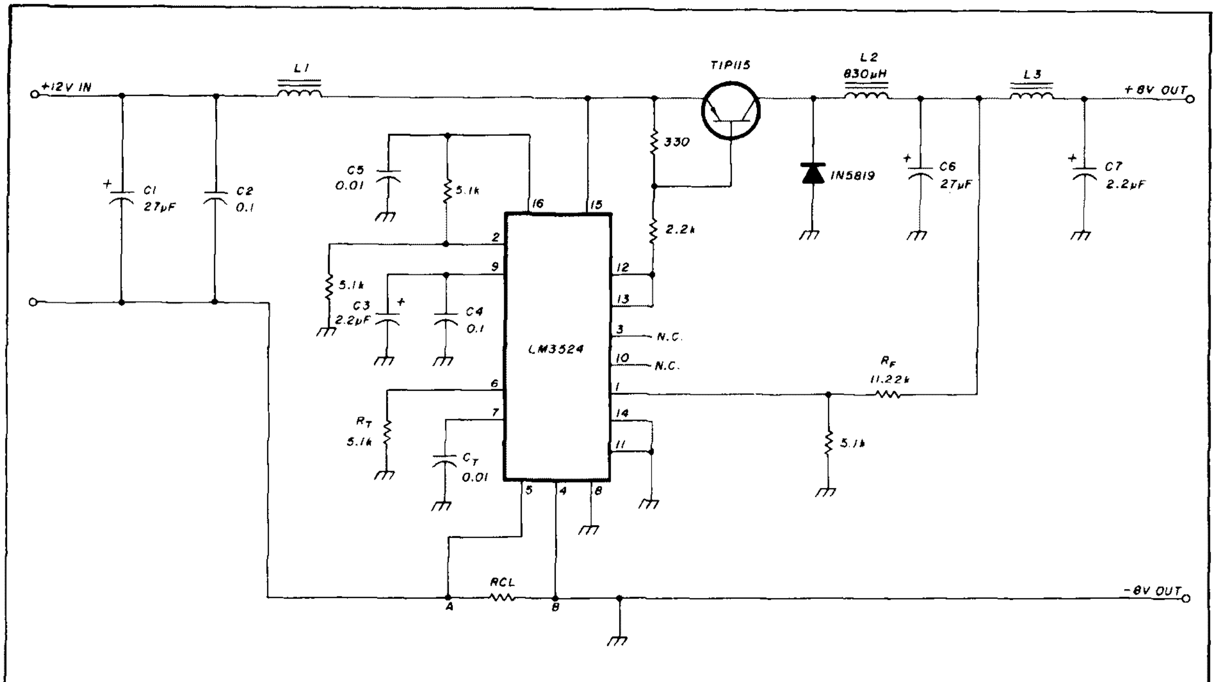


fig. 4. Step-down forward converter provides 8 volts out with 12 volts applied to the input.

of this converter, approximately 20 kHz, is determined by the value of R_t and C_t. The frequency is about equal to 1 over the product of the timing Resistor R_t here and timing Capacitor C_t or:

$$f = \frac{1}{R_t\, C_t} \qquad (1)$$

The inductor L2, the heart of the unit, has an inductance of 830 μH, and consists of 72 turns of No. 26 wire wound on an 1811F1D bobbin mounted on a set of Ferroxcube® gapped cup cores (part No. 1811PA1603B9).* Though the inductor could just as well be wound on a toroid, I chose cup cores because they were available and because they're much easier to wind than toroids. I bolted them together with a nylon screw, but any nonmagnetic material, such as brass, would have been appropriate.

This supply will operate equally well with a 15, 18, or 24-volt input. To convert to a 5-volt output, change the feedback resistor R_f to 5.1 k; to fine-tune the voltage, use a 4.7-k resistor in series with a 500-ohm pot. To adjust this 8-volt supply, use a 10-k resistor in series with a 2-k pot instead of the 11.22-k resistor shown, because it isn't a standard value and would have to be made up of several resistors in series.

The feedback resistor for the circuit shown in **fig. 4** can be calculated as follows:

$$R_f = 5100\left(\frac{V_o}{2.5} - 1\right) \qquad (2)$$

V_o being the desired output voltage from the supply.

The switching transistor TIP 115 should be heat sinked to keep it from overheating. In my supply it was bolted, with a mica washer, to the circuit board upon which the supply was built to keep it from shorting to the copper foil of the circuit board.

If the output current is increased to 1.0 ampere, the value of the inductor should be decreased to 300 to 500 μH or so. In all cases, the diode should be a fast-recovery type; for maximum efficiency in low-voltage supplies of 5 to 10 volts output, a Schottky type (for example, a 1N5819) is preferred. In any event, don't use 1N4000-type diodes, which will overheat.

The value of the inductor, L2, can be calculated as follows:

$$L = \frac{2.5\ Vo\ (V_{in} - V_o)}{I_o\ V_{in}\ f_{osc}} \qquad (3)$$

V_o = output voltage
V_{in} = input voltage
I_o = output current
f_{osc} = oscillator frequency

inverted supply

Figure 6 shows a converter that gives us an inverted supply or a −15-volt supply from a positive source.

*The cup cores are available from Ferroxcube. Toroids were made by Micrometals; toroids from FairRite, Arnold Engineering, Magnetics, and other manufacturers may be used instead.

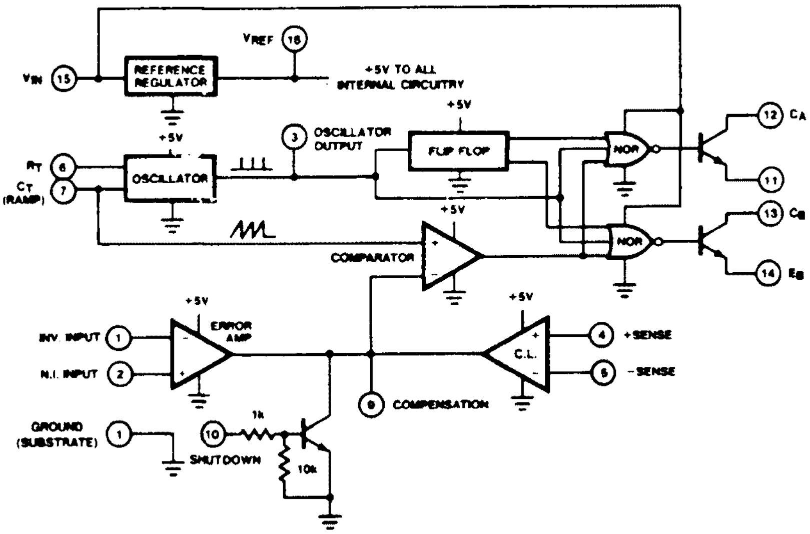


fig. 5A. Unitrode No. UC1524 series of ICs: equivalent internal block diagram.

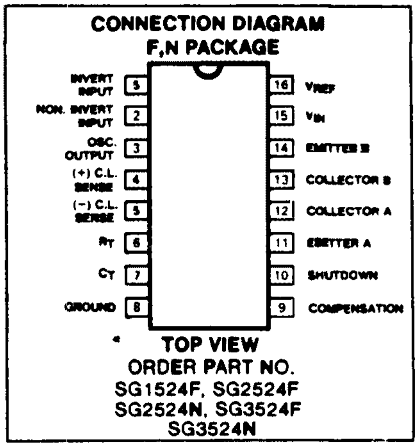


fig. 5B. UC1524 series pin configuration.

This circuit provided an efficiency of 76 percent loaded to 250 mA. The inductor measured 525 μH and consisted of 70 turns of No. 29 wire wound on a Ferroxcube cup core set of No. 1408PA1003B7 gapped cores. This is a smaller core than the one used in the buck converter shown in **fig.** 4. The frequency of this oscillator was measured at 21.2 kHz.

Do not operate any of these dc-to-dc converters without some load; if you do, the capacitor can charge up to the peak pulses applied to the inductor. One way to prevent this from happening is to modify the feedback resistor and 5.1-k resistor to ground to lower values, in order to provide some loading to the supply if you want to be able to remove the load while the supply is operating, or want to apply the load while it's operating. In this circuit, I used a Schottky diode (1N5819) with a snubber consisting of a 3.3-k resistor and a 1000-pF capacitor in series across the diode. If a fast-recovery type such as a 1N4935, 1N4936, or 1N4937 were used, the snubber could be deleted.

Since the 35.7-k feedback resistor isn't a standard value, a good substitute would be a 33-k resistor in series with a 5-k pot; with this arrangement, you'd be able to adjust the output to exactly 15 volts. The output voltage can be changed by merely changing the value of the feedback resistor.

The value of the feedback in this supply or circuit can be calculated as follows:

$$R_f = \frac{OV + 2.5}{2.5} \times 5100 \qquad (4)$$

This supply will operate just as well with an input voltage of from +12 to +24 volts. In fact, it will probably operate with an input as high as 40 volts, the maximum for the LM3524, but be sure to use a fast-recovery diode rather than a Schottky type.

boost converter

The boost converter shown in the next circuit (**fig. 7**) uses the internal switching transistors in the 3524 chip because the load was only 40 mA. The efficiency of this circuit, with an output of 24 volts at 40 mA, and an input of 12 volts, was measured at 78.6 percent. The 600-μH inductor consists of 80 turns of No.

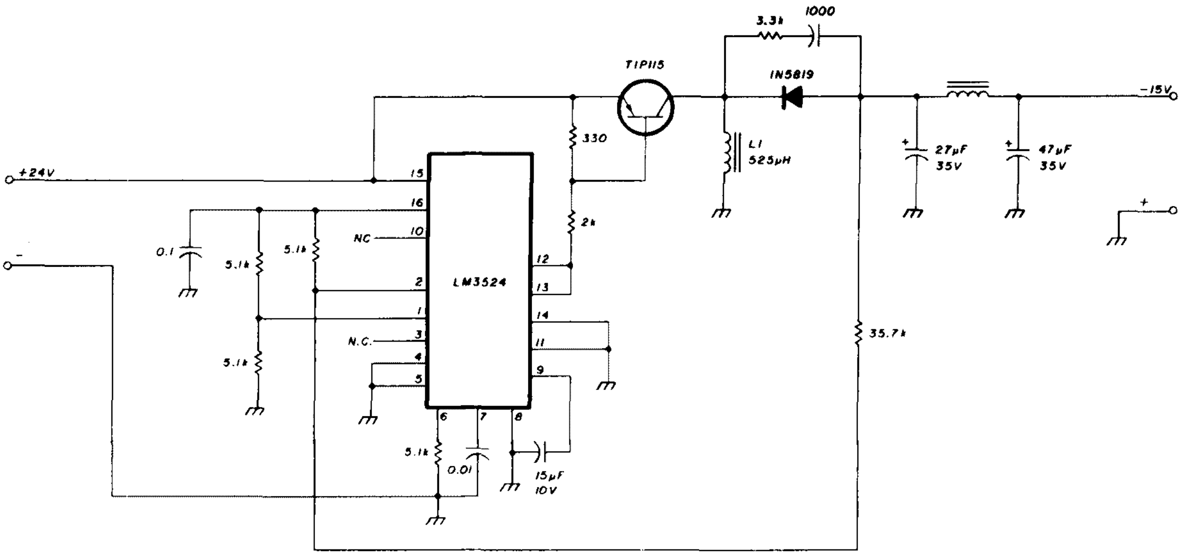


fig. 6. Inverting converter provides −15-volt output for positive input.

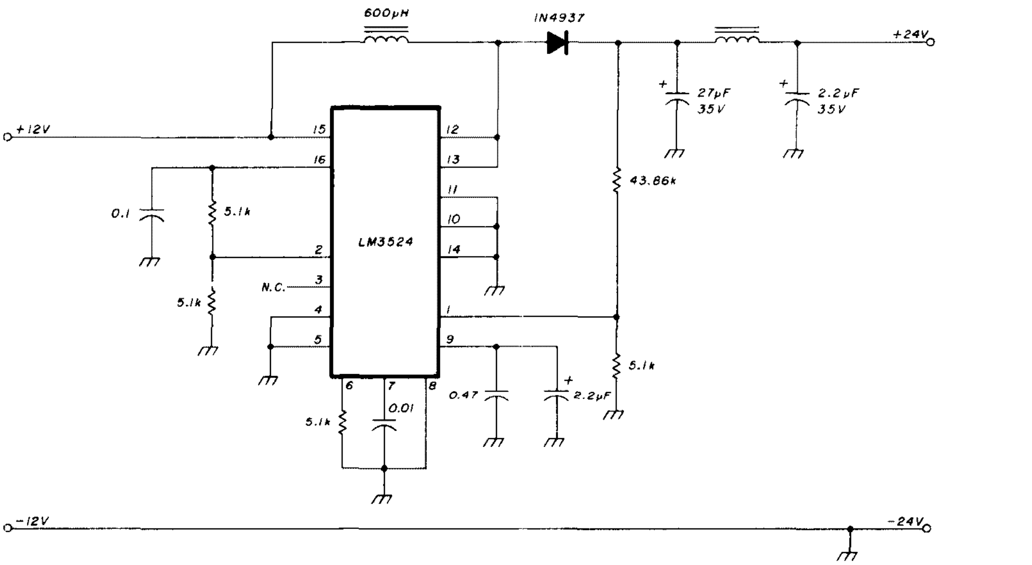


fig. 7. Boost converter is able to use the LM3524 internal switching transistors because of low-current operation.

32 wire wound on a Ferroxcube core (No. 1107PA1003B7), which is smaller than those used in the other circuits. In all cases, when you use cup cores, be sure to adjust the wire size to fill the bobbin completely for the inductance required. Toroids can also be used in these circuits.

The component values of a large part of the circuitry are similar to the other circuits used in **figs. 4** and **6**.

Earlier I mentioned a problem with the basic boost circuit given that there's no easy way to current limit it when the switching transistor isn't connected between the input and output. In any of the circuits where the switching transistor is connected between the input and output, the current limit comparator at pins 4 and 5 can be connected across a limit resistor as shown in **fig. 4**. In the inverting supply, the resistor can be

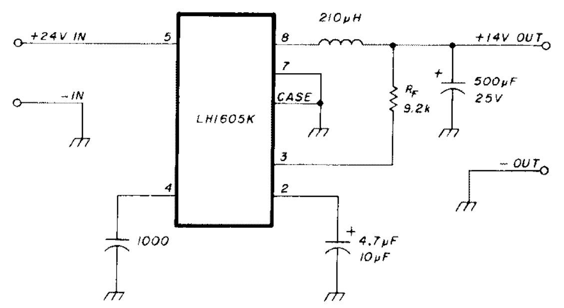


fig. 8A. Circuit diagram of simple buck converter using National LH1605K IC.

placed in series with the diode and ground, with the ends of the resistor connected to pins 4 and 5; be careful to observe the correct polarity.

simple buck converter

A rather simple buck converter can be built around the National LH1605K, a device with eight leads, contained in a TO3 package.* The internal schematic and complete circuit diagram are shown in **fig. 8**. The switching transistor and diode are contained in the same package, so the entire circuit consists of three capacitors, one resistor, and one inductor in addition to the IC. The internal transistor and diode combination is capable of supplying an output current of 5 amps. Needless to say, it's necessary to use some form of heat sink. The maximum input voltage, 35 volts, will supply an output voltage as low as 3 volts and as high as 30. The feedback resistor can be calculated as follows:

$$\frac{2 \times 10^3 \, (V_0 - 2.5)}{2.5} \qquad \textbf{(5)}$$

If a 15-volt output is desired, then R_f would be 10 k; for a 5-volt output, it would be 2 k. With a 12-volt input and a 5-volt output, I measured an efficiency of 68 to 69.5 percent with a 5-volt load of 600 mA to 1 ampere. With a 24-volt input and a 14-volt output, the efficiency varied from 73.5 percent to 79 percent because the load was varied from 300 mA to 2 amperes. If a step-down regulator is required, this chip would surely be appropriate. The inductor in my unit measured 210 µH and consisted of 35.5 turns of No. 20 wire wound on a Ferroxcube cup core set (No. 2616PA170368) held together by a nylon screw, which also was used to mount it. This chip can be used only as a buck converter. In my unit, R_f was a pot that could be set for any output voltage as long as it was several volts less than the input.

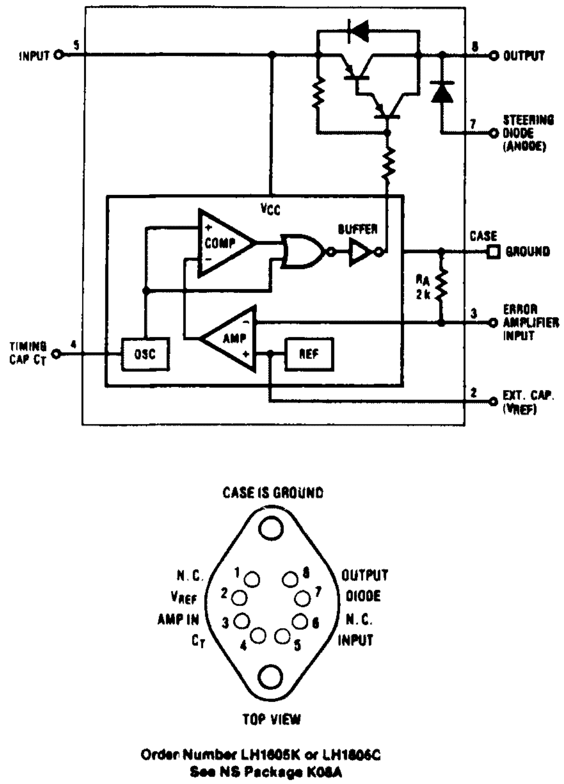


fig. 8B. National LH1605K IC: internal diagram and pin configuration.

other possibilities

Lambda's 6300 series of PWM regulators come in the same TO3 package with eight leads. These units can be used in a number of circuits — buck, boost, or inverting.

It's possible to build multiple output supplies using PWM chips. If the supplies require that all the outputs need to be regulated rather closely under varying load conditions, then you could probably build, as I have, several regulated supplies with all chips running at the same frequency. One chip uses R_t and C_t connected to the appropriate pins. Tie pin 3 of all chips together, and pin 7 of all chips together.

You can obtain a ± supply from one buck regulator which will track quite well even though one supply or output is sampled via the feedback resistor. It works best if the - supply is loaded to only 10 to 25 percent of the load on the + supply (see **fig. 9**). If the load on the + supply is removed with a load on

*The National LH1605K chip, most of the diodes, and the switching transistors used in these circuits are available from Digi-Key Corporation, P.O. Box 677, Thief River Falls, Minnesota 56701.

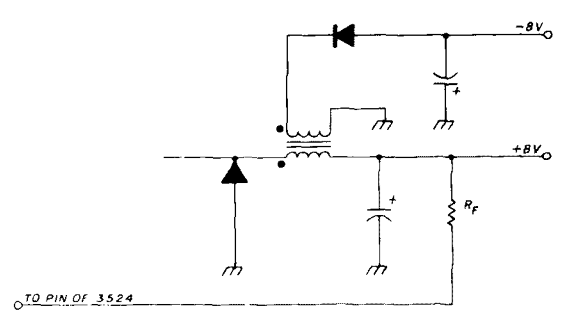


fig. 9. Dual-voltage supply uses single buck regulator.

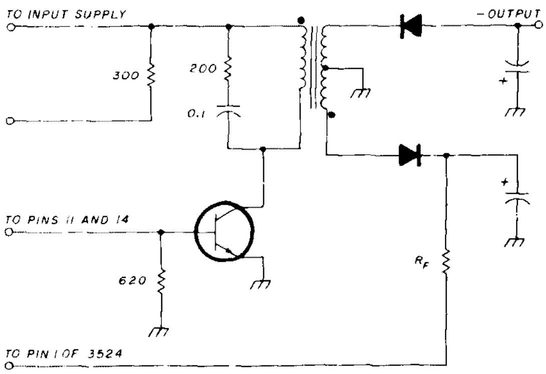


fig. 10. Dual-voltage supply uses center tapped transformer.

the - supply connected, the - voltage will drop considerably because the pulse width will be reduced severely — but with loads on both supplies, the voltages will track quite well. The inductor in this circuit was wound with 76 turns of bifilar No. 30 wire.

Another way to obtain a dual supply is to use a center-tapped transformer, as shown in **fig. 10.**

conclusion

In closing I might mention that since these supplies run at 20 kHz, good low-frequency rf practices should be followed in wiring. It would be best if pin 10 of the chip were grounded; when a supply I built with some new chips operated erratically, I found that pin 10 was picking up some hash from the circuitry and tending to shut down the regulator.

If you don't have a large assortment of wire sizes, you can vary the wire size to fit what you have on hand. The exact inductance of the inductors in the circuits isn't critical; a ± 15 to 20 percent variation from the detailed values would probably work just as well.

ham radio

ham radio TECHNIQUES

Bill Orr, W6SAI

"white noise" revisited

In my January and June, 1987, columns I discussed the interesting phenomenon known as "white noise" or "reciprocal mixing" (see these columns for background information). It's interesting to note that *Radio Communication*, the monthly publication of the Radio Society of Great Britain, discusses this subject in detail in their equipment review column, but little is said about this subject in Amateur Radio magazine equipment review columns in United States publications. My opinion is that the subject won't go away if you ignore it!

The RSGB reviews indicate transmitter noise sideband performance at 10 kHz off-tune as the "standard of performance" they measure, but they also provide reciprocal noise measurements at 2, 3, 5, 10, 20, 30, 50 and 100 kHz off tune. This is very useful information, and it's a pity that more of it isn't available on this side of the pond. I'm sure that as time goes on, the data will be available for general consumption. While publications other than this one may be oblivious to the fact, the readers of this column are not, judging from my mail on the subject.

In this regard, the November, 1986, issue of *rf Design* magazine[1] included an article entitled "Broadband Noise Improvement in RF Power Amplifiers" by Franke and DeLeon of the ECI Division of E-Systems, Inc. In brief, the authors maintained that operation of a high power transmitter in the vicinity of a sensitive receiver can result in the degradation of the receiver due to broadband transmitter noise.

This is nothing new. I remember back in 1935, when I first got on 20-meter phone, a local DXer had great, hissing sidebands on his a-m transmitter. Everyone objected. The DXer, who was an engineer, literally tore his rig apart trying to find the cause of the noise. He never found it, and the cause remained a mystery. The noise wasn't caused by a phase-lock loop circuit, either — they hadn't been invented yet!

In their article, Franke and DeLeon pointed out that the level of white noise is greatest close to the carrier frequency of the transmitter, and drops off gradually as the observation frequency departs from the carrier frequency (**fig. 1**). Unfortunately, the noise can't be filtered out at the receiver. They noted that the presence of close-in broadband noise isn't unexpected, considering the shape of the gain response of a bipolar transistor (**fig. 2**), which exhibits greater gain at frequencies lower than the normal operating region. This indicates to me that such amplifier stages are "wide open" to pass any close-in noise generated in the earlier stages of the transmitter.

Franke and DeLeon attacked this problem by using low frequency loading in the amplifier stages to reduce low frequency gain without sacrificing high frequency gain. In their example, the amplifier stages worked above 200 MHz, and they set about to lower stage gain at frequencies below 50 MHz. A sample of this design technique is shown in **fig. 3**.

In the base circuit of Q1, the rf choke (L1) is the normal one for the operating frequency. Choke L2 presents a high impedance down to very low frequencies and the low frequency (noise) energy flows through load resistor R1, which is in the range of 5 to 10 ohms. The base circuit, then, is loaded by R1 at low frequencies where power gain is high.

A similar scheme is used in the collector circuit. Choke L3 is normal for the operating frequency. However, L3 and hf bypass capacitor C1 form an L-network that transforms the value of resistor R2 to a value that will heavily load the collector at the lower frequencies. At the operating frequency, L4 appears as an open circuit and capacitor C2 provides a very low impedance, which results in the collector feedback network shown in the small illustration. Below the normal operating range of the amplifier the input impedance to the network looks resistive, approaching the value of R2, which is typically 10 to 20 ohms.

The authors provided "before and after" illustrations of broadband noise density with and without low frequency load resistance. In addition, they point out that FETs (Field Effect Transistors) have 10 to 15 dB lower broad-

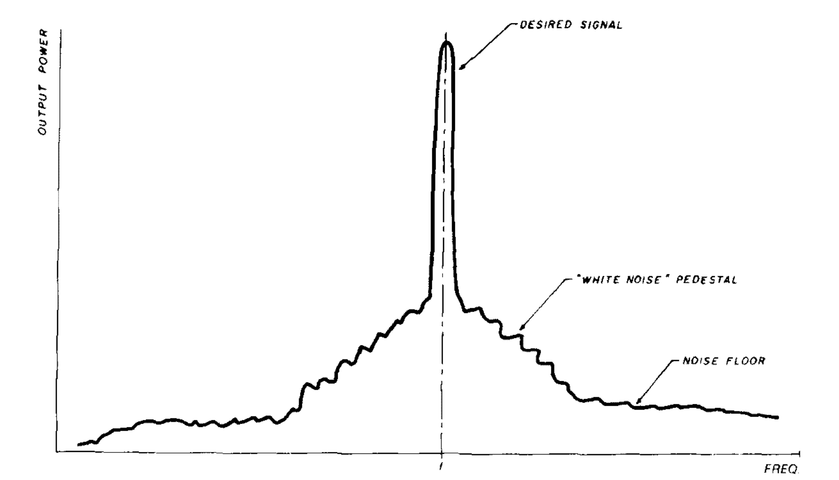


fig. 1. Level of white noise, greatest close to the carrier frequency of the transmitter, drops off gradually as the observation frequency departs from the carrier frequency.

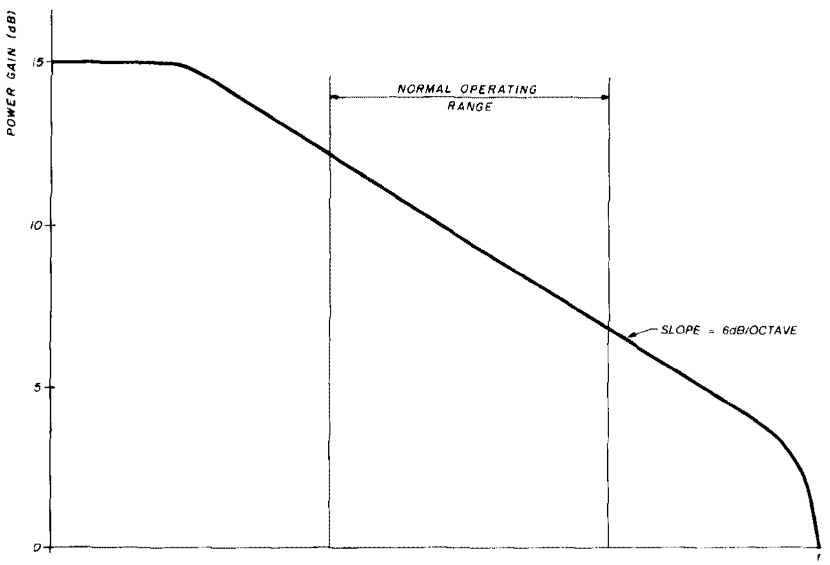


fig. 2. Bipolar transistor exhibits greater gain at frequencies lower than the normal operating range. Broadband noise power is predominantly low-frequency noise.

band noise than a comparable bipolar power transistor. It appears that this technique is worth considering in the continuing battle against the white noise problem.

It's obvious that progress is being made in this important area. Dealing with the problem of broadband noise (as far as ham equipment goes) is in about the same stage of development that receiver overload was 15 years ago. The latter problem has been solved, and I'm confident that this one is on the edge of being solved. Time will tell!

more on telephone interference

The following information was provided by W6BIP ("Bip"):

With regard to telephone interference caused by an Amateur station, recent editions of the ***ARRL Handbook*** *and other publications have suggested that compensation networks that are RFI-free can be obtained from the telephone companies for installation in an RFI-prone instrument. Unfortunately, the compensation networks discussed have been discontinued and deleted from the AT&T inventory. Bad news!*

W6BIP reports, however, that the new replacement line filter module Z-100A does the job in most cases. It consists of two 7.2-mH (8 ohms dc resistance) rf chokes wound on small ferrite cores. Contained in a plastic box that has matching connectors to place in series with the line, it can be bought at AT&T company phone stores or ordered by phone from the AT&T National Service Center in St. Louis, Missouri (800 222-3111). The stock number of the line filter is SKU-57210. A second line filter (model Z-101A), stock number SKU-57293, is available for use with wall-mounted phones.

W6BIP mentions that in addition to the line filter module, some phones may require additional rf filters in the form of a 0.01-μF ceramic capacitor placed across the microphone and a second one across the earphone. Experience has shown that the 3/16-inch diameter capacitors are superior in RFI reduction to the common 3/8-inch diameter capacitors. The value of 0.01 μF is not critical; values between 0.001 and 0.047 μF can be tried. When used in conjunction with the Z-100A filter module, they substantially reduce interference.

From experience, W6BIP says this combination of capacitors and filter module should work for those Amateurs using 1 kW input, or less, with their horizontal antennas at least 25 feet above and away from the affected telephones. For those using vertical antennas with radials on the roof, or slopers or end-fed antennas close to the roof, so much rf seems to enter the house wiring and indoor telephone lines that the filtering described may be inadequate.

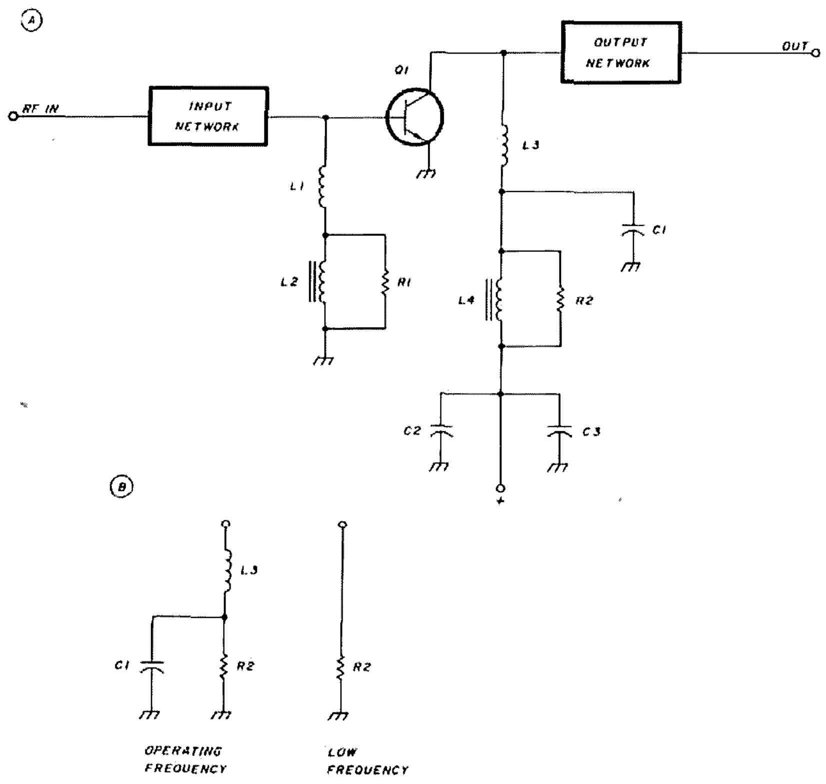


fig. 3. Design technique for low-frequency loading.

the "wideband dipole" — a different approach

Eighty-meter operators have been continually frustrated by the problem of getting an antenna that will show a low value of SWR across the whole band (3.5 to 4.0 MHz). Many modern transceivers require a feed line SWR of less than 2:1 to function properly.

A conventional dipole, cut to mid-band and fed with a 50-ohm coax line has an operational bandwidth of 170 to 190 kHz between the 2:1 SWR points, depending upon the height above ground. This means that such an antenna, cut for the high end of the band (phone) is useless at the low end of the band (CW).

Bill McLeod, VK3MI, has an interesting approach to this problem, as shown in **fig. 4**. His antenna design appeared in the April, 1986, issue of the *Journal of the Wireless Institute of Australia*. His idea consists of using a quarter-wave 73-ohm transformer made of RG-59/U coax plus a reactance compensation capacitor to introduce a deliberate mismatch at the antenna. The result is a poorer SWR level at the resonant frequency of the antenna, but a flatter SWR response across the band of interest.

Using a dipole cut for 3.7 MHz, Bill measured an SWR value of less than 2:1 over a bandwidth of 420 kHz, as shown in the illustration.

It seems to me that with the dipole cut for a slightly higher frequency (say, 3750 kHz) and with adjustment of the reactance capacitor, it may be possible to "stretch" the 2:1 operating bandwidth to cover the complete 80-meter band.

The capacitor should be a high-voltage mica type, or it may be made from a length of coax line open at the far end. The capacitive stub can be taped to the feed line, if desired.

One trick for achieving better bandwidth is to use this scheme with a

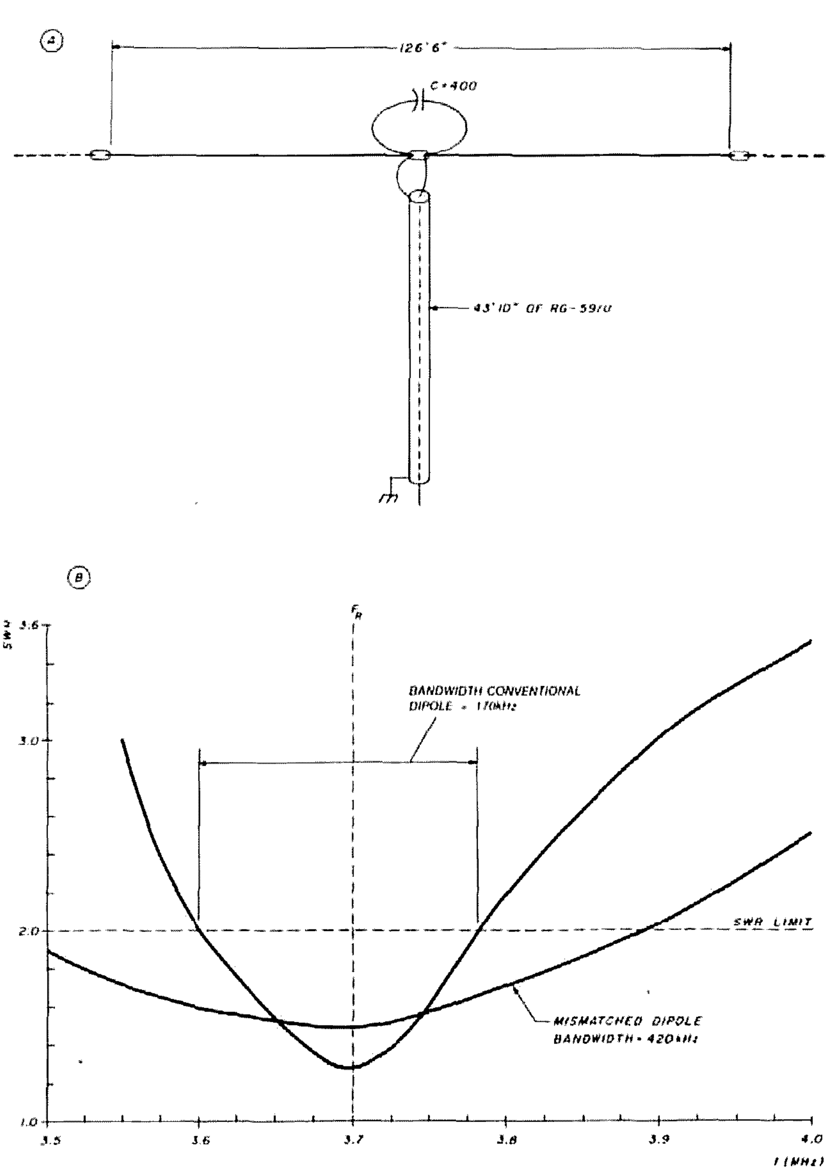


fig. 4. (A) VK3MI wideband dipole for 80 meters; (B) bandwidth of VK3MI and conventional dipole.

"fat" dipole. If the dipole halves were made of 300-ohm transmitting twin-lead, with the wires shorted together at the ends, the additional conductor area might achieve substantially better bandwidth response. In any event, this looks like a good idea to experiment with.

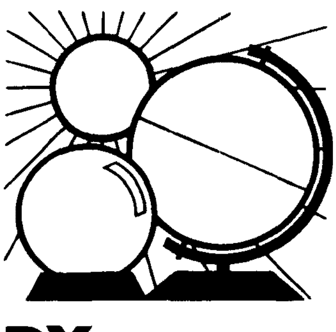
EME directory

The 144-MHz EME (moonbounce) directory is available again. For a copy, send five first-class stamps or five IRCs to me (no envelope required) at Box 7508, Menlo Park, California 94025. The directory is a 36-page list of EME operators, their QTHs, and the equipment they use.

reference

1. Franke and DeLeon, "Broadband Noise Improvement in rf Power Amplifiers," *rf Design*, November, 1986 (*rf Design*, 6530 South Yosemite Street, Englewood, Colorado 80111).

ham radio



DX FORECASTER

Garth Stonehocker, K0RYW

equinox season DX

Sunspot minimum appears to be over until nearly eleven years hence. Even though a year or so will pass before momentum helps the new cycle to build up to its maximum rate, the return of the 27-day cycle (each solar rotation) has increased the number and size of solar flares and has solar flux energy topping 100 units again. This is expected to continue, gradually increasing in 27-day cycle activity until a sunspot region comes around at least three or four times before dying away. In the meantime, the geomagnetic disturbances will continue to be mainly variations in the solar wind from coronal holes, with an occasional flare-induced geomagnetic event. In either case, the disturbances affect DX fun adversely.

Geomagnetic disturbances, or storms, affect propagation — and DX — in four ways. First, particles from the sun entering the auroral zone at 50 to 70 degrees North and South latitudes come down into the ionospheric D and E regions, increasing signal absorption. This results in weak east-west path signals and few transpolar signals.

Second, the F region of the ionosphere (for stations in the United States, this is south of the auroral zone) has a depleted area of electrons that forms an electron density trough. The maximum usable frequency (MUF) for paths through this area decreases by 30 to 40 percent (see the January, 1986, *DX Forecaster* for tables of MUF statistics).

Third, and still further south at 20 degrees from the geomagnetic equator, an equivalent-size enhancement of the F region occurs, resulting in evening Transequatorial (TE) openings during the equinox and winter seasons. These three effects vary in intensity and time on a short to long basis (seconds through hours), causing what we experience as fading and blackout. These effects continue to occur mainly each night for two to three days before ionospheric equilibrium is re-established. The larger the geomagnetic storm (the higher the value of the K or A indicies), the closer to the equator these effects occur.

Fourth, the particles form a reflective curtain along the equatorial side of the auroral zone (for those of us in North America, this is south), enhancing VHF auroral scatter propagation. Six-meter openings to Europe are one result of this phenomenon. Just as the particle density and speed of the solar wind vary, so do the characteristics of the geomagnetic field and ionosphere. Ionospheric variations cause signal reflection focusing and defocusing, which simply means that the signals arriving at your QTH will vary in both strength and angle of arrival from all four directions. Some locations you haven't heard from in a long time may suddenly be workable.

last-minute forecast

The higher-level 27-day activity may push up the maximum usable frequencies (MUF) during the first and second weeks of October, giving better 10-, 12-, and 15-meter DX. Transequatorial one-long-hop propagation is expected to be underway again, especially around the 5th, 15th and 23rd of the month. This is because of a higher probability of geomagnetic disturbance at those times. During those same disturbed periods, the lower band's MUFs should decrease by 15 to 25 percent for

a couple of days at a time. This will be particularly noticeable on east-west paths, and with noticeable QSB. Otherwise, the lower bands should be best during the last two weeks of the month because of higher signal strengths.

The Orionids meteor shower will be visible from the 15th to 24th of October, with a maximum rate of between 10 to 20 per hour on the 20th to 21st of the month. The moon is full on the 7th, and perigee occurs on the 4th and 30th. A penumbra eclipse of the moon occurs on October 7.

band-by-band summary

Ten, twelve, fifteen, and twenty meters will be open from morning to early evening almost every day, and to most areas of the world. The openings on the higher of these bands will be shorter and will occur closer to local noon. Transequatorial propagation on these bands will more likely occur toward evening during conditions of higher solar flux and a disturbed geomagnetic field.

Thirty and forty meters will be useful almost 24 hours a day. Daytime conditions will resemble those on 20 meters. Skip distances and signal strength may decrease during midday of those days that coincide with the higher solar flux values. Nighttime DX will be good except after days of high MUF conditions and geomagnetic disturbances. Look for DX from unusual places on east, north, and west paths during this time. The usable distance is expected to be somewhat less than that on 20 meters in daytime and greater than that on 80 meters at night.

Eighty and one-sixty meters will exhibit short-skip propagation during the daylight hours and lengthen for DX at dusk. These bands follow the darkness path, opening to the east just before your sunset, swinging more to the south near midnight, and ending up in the Pacific areas during the hour or so before dawn. The 160-meter band opens later and ends earlier than 80.

ham radio

OCTOBER

WESTERN USA

GMT	PDT	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	5:00	20	40	20	10	12	12	10	20
0100	6:00	20	40	20	10	12	★12	10	20
0200	7:00	20	40	20	12	12	★12	10	20
0300	8:00	30	40	20	15	12	★12	15	20
0400	9:00	30	*40*	20	15	15	12	15	30
0500	10:00	30	*40*	30	20	15	12	15	30
0600	11:00	40	*40*	30	20	20	15	15	40
0700	12:00	40	*40*	*30*	20	20	15	20	40
0800	1:00	*40*	*40*	*30*	*20*	*20*	20	*20*	40
0900	2:00	*40*	*40*	*30*	*20*	*20*	20	*20*	40
1000	3:00	*40*	*40*	*30*	*20*	*30*	*20*	*20*	*40*
1100	4:00	*40*	30	*30*	*20*	*30*	*20*	*20*	*40*
1200	5:00	*40*	30	15	*30*	*30*	*20*	*20*	*40*
1300	6:00	*40*	20	12	20	*30*	*30*	*20*	*40*
1400	7:00	30	20	10	12	*20*	*30*	*30*	*40*
1500	8:00	40	20	10	10	20	*30*	*30*	*40*
1600	9:00	40	20	10	10	15	*20*	*30*	*40*
1700	10:00	40	20	10	10	15	20	20	*40*
1800	11:00	*40*	20	10	10	12	20	20	40
1900	12:00	*40*	20	10	10	12	15	★30	20
2000	1:00	*40*	30	12	10	12	15	20	20
2100	2:00	40	30	15	10	12	15	20	20
2200	3:00	40	40	15	10	12	12	15	20
2300	4:00	30	40	20	10	12	12	12	15

MID USA

GMT	MDT	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN	CDT
0000	6:00	20	40	20	10	12	12	10	20	7:00
0100	7:00	★30	40	20	12	12	12	12	20	8:00
0200	8:00	30	40	20	12	12	12	15	30	9:00
0300	9:00	30	40	20	15	15	12	15	30	10:00
0400	10:00	30	*40*	20	15	15	15	20	40	11:00
0500	11:00	40	*40*	30	20	20	15	20	40	12:00
0600	12:00	40	*40*	30	20	20	20	20	40	1:00
0700	1:00	*40*	*40*	*30*	*20*	20	*30*	20	40	2:00
0800	2:00	*40*	*40*	*30*	*20*	*30*	*30*	*20*	40	3:00
0900	3:00	*40*	*40*	*30*	*20*	*30*	*30*	*30*	40	4:00
1000	4:00	*40*	30	*30*	*20*	*30*	*30*	*30*	*40*	5:00
1100	5:00	*40*	20	20	*20*	*30*	*30*	*30*	*40*	6:00
1200	6:00	30	20	15	15	*30*	*30*	*20*	*40*	7:00
1300	7:00	30	20	12	15	*20*	*20*	*20*	*40*	8:00
1400	8:00	30	20	10	12	20	*30*	*20*	*40*	9:00
1500	9:00	30	20	10	10	15	*30*	*20*	*40*	10:00
1600	10:00	40	20	10	10	15	*20*	*20*	*40*	11:00
1700	11:00	40	20	10	10	15	20	20	*40*	12:00
1800	12:00	*40*	20	10	10	12	20	20	30	1:00
1900	1:00	*40*	30	10	10	12	15	20	20	2:00
2000	2:00	*40*	30	12	10	12	15	15	20	3:00
2100	3:00	*40*	30	15	10	12	12	12	20	4:00
2200	4:00	*40*	40	15	10	12	12	★12	20	5:00
2300	5:00	40	40	20	10	12	12	12	20	6:00

EASTERN USA

GMT	EDT	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE CARIBBEAN S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	8:00	30	40	20	12	12	12	12	20
0100	9:00	30	40	20	12	15	12	15	30
0200	10:00	40	40	20	15	15	12	20	30
0300	11:00	40	40	20	20	15	15	20	★40
0400	12:00	40	*40*	20	20	20	15	20	40
0500	1:00	*40*	*40*	*30*	20	20	15	20	40
0600	2:00	*40*	*40*	*30*	*20*	20	20	20	40
0700	3:00	*40*	*40*	*30*	*20*	*30*	20	*20*	40
0800	4:00	*40*	*40*	*30*	*20*	*30*	20	*20*	*40*
0900	5:00	*40*	*30*	20	*20*	*30*	20	*30*	*40*
1000	6:00	20	20	12	*20*	*30*	*20*	*30*	*40*
1100	7:00	20	20	10	15	*20*	*30*	*30*	40
1200	8:00	20	20	10	15	*20*	*30*	*20*	40
1300	9:00	20	20	10	12	20	*30*	*20*	*40*
1400	10:00	30	20	10	★12	15	*30*	*20*	*40*
1500	11:00	30	20	10	10	15	*30*	*20*	*40*
1600	12:00	40	20	10	10	15	*20*	*20*	*40*
1700	1:00	40	20	10	10	★15	20	*20*	*40*
1800	2:00	40	20	10	10	12	20	20	*40*
1900	3:00	*40*	30	10	10	12	15	20	30
2000	4:00	*40*	30	12	10	12	15	15	20
2100	5:00	*40*	30	15	10	12	12	12	20
2200	6:00	*40*	40	15	10	12	12	★12	20
2300	7:00	*40*	40	20	10	12	12	10	20

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

locator field list

Do you like challenges? If the widespread acceptance of the DXCC, WAZ, and sundry other operating awards proudly displayed by Amateurs throughout the world is any indication, I'm sure you do.

Folke Rosvall, SM5AGM, has taken it upon himself to compile, on a per-band basis, the total number of fields worked by individuals. His list appears in *ham radio* four times a year (see page 75 of the July issue for the first list published in these pages).

"But," you ask, "What's a field?" Glad you asked. According to the Maidenhead locator system, the world is divided into 324 fields or areas, each 20 degrees wide in longitude and 10 degrees wide in latitude. Though most encompass land masses, quite a few do not; this means no countries, no islands, no reefs — just water. So even if you've worked *every country in the world and* your name is at the top of the honor roll, you still probably haven't worked all the fields. For example, *I'm very active on 80 meters, yet I've been* able to snag only 148 out of 324 fields. I can think of a number of other 80 meter operators who are even more active than I am.

Have I tickled your competitive spirit? Think of the ultimate challenge: *work all fields on all 19 bands on one specific mode.* Some quick calculating shows that to be . . . uh . . . 6156 contacts. That'll keep you off the streets (but probably get you into trouble with your family, your employer, etc.). Seriously, it's all for fun, and you'll learn a little more geography in the process.

All the necessary details are included on the *accompanying chart. Folke would be very glad* to hear from you. Please send your tabulations directly to him (his address at the bottom of the chart) — not to *ham radio*.

See you on 80!

Rich Rosen, K2RR

LOCATOR FIELD LIST

AJ | BJ | CJ | DJ | OJ | PJ | QJ | RJ
AI | BI | CI | DI | OI | PI | QI | RI

1987 06-30, COMPILED BY SM5AGM (JO99DK). WHO WILL BE THE FIRST RADIO AMATEUR TO WORK ALL 324 FIELDS ON THE SAME BAND?

Band	Call	Loc	Fields/Date	Call	Loc	Fields/Date	Call	Loc	Fields/Date	Call	Loc	Fields/Date	Call	Loc	Fields/Date
1.8 MHz	1 W1JR	FN	68 870501	3 SM6CTQ	JO	20 850127	5 SM0LH	JO	5 860322	7 SM0NZB	JO	2 870630			
	2 SM3LWE	JP	54 870630	4 OK1DKS	JO	9 870615	6 SM4JXG	JO	3 861231	8 SK6AW	JO	1 870630			
3.5 MHz	1 K2RR	FN	148 870630	4 SM6CCE	JO	79 850122	7 SK6AW	JO	58 870630	10 OK1DKS	JO	23 870615	13 SM0LH	JO	8 860322
	2 SM3LWE	JP	130 870630	5 SM7WT	JO	68 850125	8 SM5CAK	JO	56 860921	11 SM3CVM	JP	19 861012	14 SM4JXG	JO	7 861231
	3 W1JR	FN	102 870501	6 SM0HTO	JO	64 851230	9 SM6INC	JO	21 870630	12 KC9RG	EN	10 870630			
7 MHz	1 SM3CWE	JP	142 870630	5 SM7PKK	JO	86 870322	9 SM3CVM	JP	43 861012	13 SM5CAK	JO	11 860921			
	2 SM6CCE	JO	138 850122	6 SM6INC	JO	76 870630	10 OK1DKS	JO	19 870615	SM4JXG	JO	11 861231			
	3 W1JR	FN	119 870501	7 SK6AW	JO	67 870630	11 SM0LH	JO	15 860209	KC9RG	EN	11 870630			
	4 SM7WT	JO	47 850126	8 SM0HTO	JO	47 851230	12 9V1BH	OJ	14 870610	16 SM0NZB	JO	5 870630			
10 MHz	1 W1JR	FN	43 870501	4 SM5FUG	JO	21 860912	7 SM6MSG	JO	10 850930	10 SM0HTO	JO	7 851230	13 SM5CAK	JO	3 860921
	2 9M2FP	OJ	31 861220	5 SM5ACQ	JO	17 870625	8 SM0LH	JO	9 860322	11 SM7BDB	JO	5 850922	SM0NZB	JO	3 870630
	3 SM6INC	JO	23 870630	6 SM3CWE	JP	13 870630	SM4JXG	JO	9 861231	12 SM5PAX	JO	4 850930	15 KC9RG	EN	1 870630
14 MHz	1 SM3CWE	JP	222 870630	W1JR	FN	192 870501	7 W6DU	CM	147 860226	10 OK1DKS	JO	85 870615	13 SM5FBL	JO	44 850126
	2 SM7WT	JO	201 850131	5 SM6CCE	JO	186 850122	8 SM6INC	JO	131 870630	11 SM5CAK	JO	71 860921	14 KC9RG	EN	40 870630
	3 SM0HTO	JO	192 851231	6 SK6AW	JO	157 870630	9 SM5ACQ	JO	122 850930	12 SM0LH	JO	67 860212	15 SM4JXG	JO	37 861231
18 MHz	1 SM6INC	JO	18 870630	3 SM7BDB	JO	8 850922	5 SM0LH	JO	5 860322	SM0HTO	JO	3 851230	9 9V1BH	OJ	1 870610
	2 SM5ACQ	JO	12 870311	4 SM4JXG	JO	7 861231	6 SM5PAX	JO	1 850930	8 SM3CWE	JP	2 870630			
21 MHz	1 SM3CWE	JP	158 870630	4 SK6AW	JO	116 870630	7 OK1DKS	JO	68 870615	10 SM4JXG	JO	38 861231	13 W1JR	FN	12 870501
	2 SM6CCE	JO	140 850122	5 SM6INC	JO	101 870630	8 SM0HTO	JO	52 851230	11 KC9RG	EN	20 870630	14 SM5CAK	JO	10 860921
	3 SM7WT	JO	131 850125	6 SM5ACQ	JO	95 850930	9 SM0LH	JO	44 860209	12 SM3CVM	JP	24 861012			
24 MHz	1 W1JR	FN	21 870501	3 SM0HTO	JO	5 851230	SM5ACQ	JO	5 870508	7 SM7BDB	JO	2 850922	9V1BH	OJ	1 870610
	2 SM6INC	JO	12 870630	SM4JXG	JO	5 861231	6 KC9RG	EN	3 870630	8 SM0LH	JO	1 860209	SM3CWE	JP	1 870630
28 MHz	1 DF2NJ	JO	159 851111	5 SM6CCE	JO	126 850122	9 SM5HJV	JO	93 860017	13 W1JR	FN	20 870501	17 SM4JXG	JO	12 861231
	2 SM6LIF	JO	140 850[illegible]	6 SM3CWE	JP	120 870630	10 SK6AW	JO	90 870630	14 SM0JXA	JO	21 861101	18 SM5CAK	JO	9 860921
	3 SM0HTO	JO	139 851230	7 SM6INC	JO	111 870630	11 SM5ACQ	JO	53 850930	15 OK1DKS	JO	20 870615	19 SM3CVM	JP	5 861012
	4 SM7LXV	JO	127 850[illegible]	8 SM7WT	JO	108 850125	12 SM0LH	JO	12 860212	16 KC9RG	EN	17 870630	SM0NZB	JO	5 870630
50 MHz	1 WA1OUB	FN	46 860601	W1JR	FN	41 870501	5 W6RXQ	CM	15 870630	7 JJ1GTC	QM	5 861212			
	2 N0LL	EM	41 861106	4 KA9MGR	FN	16 860311	6 K1DW	FN	14 870630	KC9RG	EN	5 870630			
144 MHz	1 SM7BAE	JO	45 870214	5 SM2GGF	KP	37 850622	9 LU3ZV	JN	32 831231	OZ1EMR	JO	31 861224	17 OH7PI	KP	28 831231
	2 VE7BQH	CN	42 870113	6 Y22ME	JO	36 861231	WA1JXN	DN	32 840608	14 SM4IVE	JO	30 840609	W5UN	DM	28 840428
	3 DL8DAT	JO	41 870220	7 YU3WV	JN	35 870321	I4CIV	JN	32 850110	WA4NJP	EM	30 840903	K0BSI	EM	29 850110
	4 K1WHS	FN	38 860310	8 SM6CVI	JO	34 860930	12 I6BST	JN	31 840909	16 K0UQ	DN	29 851231	OH1NS	KP	25 850331
220 MHz	1 W1JR	FN	10 870501	2 KA9MGR	FN	4 850314	3 W6RXQ	CM	1 870630						
432 MHz	1 K2UYH	FN	30 850311	5 W5LUA	EM	28 840428	9 VE4MA	EN	23 830301	13 K1FO	FN	19 850318	17 DL9LX	JO	10 830622
	DL9KR	JO	33 850001	6 W7GBI	DM	27 840505	10 SM5CAU	JO	21 821231	Y22ME	JO	19 861231	18 I1CZW	JO	7 850630
	3 YU1AW	KN	30 860407	7 OK1KIR	JN	26 860221	SOTMS	JO	21 860617	15 SM6DJW	JO	18 851231	SM6FYU	JO	2 860331
	4 W7JJR	FN	29 870501	SM3AKW	JP	26 851231	12 OH6NU	KP	20 821231	16 W7HAH	DN	12 860314	20 SM6HYC	JO	6 841231
902 MHz	1 W1JR	FN	7 870501												
1.3 GHz	1 K2UYH	FN	20 850301	W7GBI	DM	13 840505	OE9XXI	JN	7 850317	SM0DJW	JO	5 851231	W1JR	FN	4 870501
	2 OK1KIR	JN	17 850221	6 SM6CKU	JO	12 821231	OZ3ZW	JO	7 850630	SM3AKW	JP	5 861231	18 K1FO	FN	3 850318
	3 OE9XXI	JN	16 850330	7 YU1AW	KN	11 860407	11 DL7YC	JO	6 840411	15 SM0PYP	JO	4 830331	SK5EW	JO	3 850301
	4 W5LUA	EM	13 840428	8 W6YFK	CM	7 840506	12 SM6HYG	JO	5 821231	SM4AXY	JO	3 831231	SM6ESC	JO	3 850630
2.3 GHz	1 W4HHK	EM	4 850304	W6YFK	CM	3 840506	OK1DKS	JO	2 870615	WA4HGN	EM	1 840505			
	OE9XXI	JN	4 850331	5 OK1KIR	JN	2 850221	8 PA0SSB	JO	1 821231	OZ1CFO	JO	1 850820			
	3 SM6HYG	JO	1 830310	W1JR	FN	2 870501	W5LUA	EM	1 840428	W6RXQ	CM	1 870630			
3.4 GHz	1 SM6HYG	JO	1 850914												
5.7 GHz	1 SM6HYG	JO	1 850914	OZ1CFO	JO	1 850930									
10 GHz	1 SM0DJW	JO	2 850630	W6RXQ	CM	2 870630	SM7ECM	JO	1 850730						
	YU1AW	KN	2 860224	4 SM6HYG	JO	1 850914	W1JR	FN	1 870501						

This list shows the number of fields worked according to the Maidenhead Locator System. A field is a block of 20° longitude × 10° latitude. Rules: 1. All fields must have been worked [illegible] 2. All stations involved must be on the earth's surface. 3. QSL cards are not required if you are sure that the other station considers the QSO complete. 4. [illegible] 5. There is no starting time for contacts to be eligible. A world map showing the 324 fields can be found in "The Radio Amateur's World Locator Atlas" that normally should be available at your national amateur radio society.

Compiled quarterly since 1982, the list shows the situation on March 31, June 30, September 30 and December 31 at 2400 UT. Please send your info as soon as possible after each date to SM5AGM, Folke Rosvall, Vastersvangen 50, S-184 00 Akersberga, Sweden. Tel: 0764 27638

NEW products

personal packet mailbox

The Kantronics Personal Packet Mailbox is an inexpensive — $39.95 — firmware option that allows your Kantronics packet communicator (the KPC-1, KPC-2, KPC 2400 and the KAM) to function as a self-contained personal mailbox system.

Until now, most popular packet mailbox systems relied on personal computers such as the Xerox 820 or IBM XT using special packet bulletin-board software written by WORLI or W7MBL. The Kantronics personal mailbox eliminates the need to tie up (and run continuously) your expensive PC for simple mailbox operations.

As with other Kantronics firmware updates, installation is as simple as installing a new EPROM. After installation you'll have to perform a hard reset of the TNC, which involves simply moving one jumper for the first power-up. The procedure is amply covered in the documentation; several pages of instructions accompany the mailbox to supplement your original owner's manual.

The NULLS command has been deleted and eight other commands have been slightly changed. If you didn't already have the 2.3 version software, you'll benefit from the six new commands from that update built into the mailbox software.

One of the more interesting and useful of these is the LLIST (Lid LIST) command. When it's turned on, the calls entered as SUPCALLS are ignored: they can't digipeat through your station, don't show on the MHEARD list, won't receive a (DM) if they try to connect to you, and can't use your mailbox. As far as your TNC is concerned, these stations just don't exist!

Another useful command is MBEACON; when it's off, packets sent as beacons or ID's aren't monitored.

Once the mailbox is installed and operating, you must enter your call. If you don't, the CMD: prompt won't appear. Once your call is "permed" into memory, you'll come up in the command mode immediately.

On the air the mailbox responds to users' commands similar to those found on many popular WORLI-type packet bulletin boards (LIST, READ, SEND, KILL, and BYE). At your end, you'll use seven others to enter, list, or delete messages on your mailbox, and to set some mailbox parameters. For instance, PBBS N is used to allocate the amount of TNC RAM, in 1K blocks, to be made available for the mailbox storage area. Up to 22K may be allocated providing the TNC has 32K of memory. MYPBBS is used to enter the unique callsign for the mailbox, which should be different from the call used for MYCALL. For instance, if K1ZJH were used for MYCALL, K1ZJH-1 would be acceptable for the mailbox call.

One of the nicest features of this mailbox is its transparent operation with normal packet operations from your station. You can carry on a packet QSO while another station is using the mailbox in your TNC, and by entering the command mode, you can access the mailbox even if someone is connected to you or to your mailbox.

While WORLI-type PBBSs can forward mail to your mailbox, the Kantronics mailbox has no provisions for forwarding itself. Mail sent to your mailbox is treated as "private"; unless it's addressed to the connecting station or to "ALL," it can't be LISTed, READ or KILLed by that station. Upon connecting, stations are informed of any unanswered mail.

Since messages in the mailbox are stored in volatile RAM, even momentary power outages will trash its contents unless battery backup is supplied to the TNC. As its name implies, this mailbox is intended as a "personal mailbox," either for individual use, or as a small club bulletin board for limited general-interest bulletins. Due to its limited RAM allocation, the number and size of the messages that can be stored are necessarily limited (although impressive, considering the limitations). Once the memory limit is reached, future messages are lost.

Several friends and I have been using Kantronics' personal mailbox for months with no problems. Apparently the software was well written and very carefully debugged before the first versions were released. The documentation is concise and explains operation and all of the commands except for the PBBS N command, whose parameters were somewhat ambiguous. For marks, the Kantronics' personal mailbox rates an A+; we can fully expect this product to have a significant positive impact on packet operations.

For more info contact: Kantronics, 1202 E. 23rd St., Lawrence, KS 66046.

K1ZJH

Circle #307 on Reader Service Card.

updated fm dual-bander

The new 2-meter/70 cm Dual Bander from Kenwood puts out 45 watts on 2 meters and 35 watts on 70 cm. Features include compact size (5.9 x 1.97 x 7.87 inches), and light weight (less than 4 pounds). With only three knobs and eight keys on the front panel, it's easy to operate.

The large LCD display and main knob provide excellent visibility in direct sunlight or darkness. Full duplex crossband operation via repeater is possible (assuming, of course, that a control operator is available).

The new Dual Bander offers programmable band scan and memory scan with memory channel lock-out. A lithium battery provides

NEW products

backup for ten memory channels that store frequency, offset, and subtone. For odd split or crossband operation, two channels store transmit and receive frequencies independently. Thanks to a nonvolatile operating system, all operating features remain intact — even after the memory backup cell dies. No reprogramming or board-swapping is ever necessary.

Separate antenna ports for VHF and UHF are provided. Optional features and accessories are available. For more information, contact Kenwood Communications and Test Equipment Group, 2201 E. Dominquez Street, Long Beach, California 90810.

new compact amplifier

The HL-37V from Tokyo High Power Labs is a compact amplifier designed for 144-MHz fm/SSB hand-helds and portable transceivers. The unit has a built-in variable gain RX pre-amp which uses a low noise GaAs FET.

The unit features an LED power level indicator and front panel with a smoked polycarbonate sub-panel so that LED lights can be recognized only when they're lit. Combined with a hand-held transceiver, the HL-37V boosts power from 2 or 3 watts to 30; rf driving input between 0.5 and 5 watts is accepted. A built-in RX GaAs FET preamp allows clearer reception of noisy or weak signals. Gain is continuously variable from − -20 to + 14 dB; an effective low-pass filter minimizes spurs.

Priced at $99.95, the HL-37V also features the fm/SSB mode select switch on the rear panel. A 1-second delay during changeover from RX to TX prevents relay chatter.

For details, contact Encomm Inc., 1506 Capital Avenue, Plano, Texas 75074.

Circle #304 on Reader Service Card.

RFI-free choke kit

MFJ Enterprises, Inc. offers the MFJ-701 RFI-free choke kit that eliminates RFI problems that affect TVs, radios, stereos, telephones, VCRs, computers, PA systems, burglar and fire alarms, test equipment, modems, monitors and other electronic devices.

Although winding an offending cable or wire around a ferrite toriod generally eliminates RFI, it's often difficult to find a toroid with the proper characteristics that has a large enough hole through which the end of a power cord, ac adapter, microphone cord, or speaker leads will fit. Priced at $14.95, the new MFJ-701 kit, however, gives you a package of four RFI-eliminating toroids (with complete instructions) which not only have the right properties for eliminating RFI, but separate into halves, making it easy to wind nearly any kind of wire or cable around the toriod. The toriod halves then mount in a snap-together plastic frame.

The individual toroids also snap together into a stack, increasing their effectiveness for large diameter wires when only a few turns can be wound around the toriod.

For additional information on the MFJ-701 RFI-free choke kit, contact MFJ Enterprises, Inc., 921 Louisville Road, Starkville, Mississippi 39759.

Circle #303 on Reader Service Card.

rack-mounted paging encoder

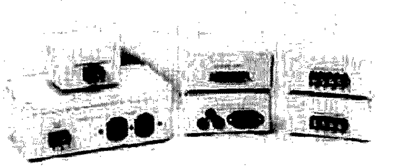
The PE-1000RMA, a rack-mounted version of Communications Specialists, Inc.'s PE-1000 Paging Encoder can be mounted in a standard 19-inch rack. Like the desktop PE-1000, the PE 1000RM is capable of 100- or 1000-call paging capacity in the two-tone sequential signaling formats. Five-tone sequential and REACH formats are also available. Programmable features include code plan and group selection, group call, duration of tone and delay timing, choice of alert tones, and automatic page. A non-volatile memory retains the programming if a power loss occurs. All standard Motorola and General Electric groups are included in every unit; non-standard tones from 250.0 Hz to 4000.0 Hz may be special-ordered. An output for printing a hard copy record of all paging activity is provided, and an automatic self-test is run each time the encoder is powered up. The price is $324.95.

For furter details or a free catalog, contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665-4296.

Circle #302 on Reader Service Card.

overvoltage protection devices

CSE Technologies has introduced a comprehensive line of Surgeguard devices that provide virtually unconditional overvoltage protection for computing, control, communications, measuring, and home entertainment equipment.



Surgeguard devices include the LSA® Line Surge Absorber, which protects against overvoltage originating from signal/data/telephone lines; the Interguard®, which protects the CCITT V.24 digital interface of terminals, computers, and modems from overvoltages originating from

NEW products

interface cable; the Powerguard*, which provides protection for equipment connected to AC mains supply; Comguard*, which protects terminal-and-modem remote data stations; Termiguard*, which protects remote terminals, and Modemguard*, which renders modems immune to overvoltage damage.

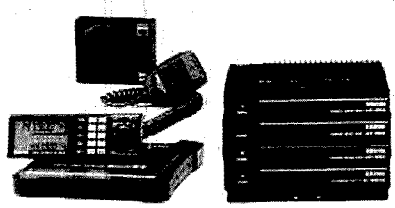
A number of different Surgeguard models can be fitted in the same enclosure. Enclosures can be stand-alone, rack-mount, or plug-in modules for circuit boards. For more information, contact CSE Technologies, P.O. Box 308, New London, Minnesota 56273.

Circle #306 on Reader Service Card.

IC-900 mobile transceiver

ICOM's new IC-900 mobile transceiver is the first fiber optic multiband mobile transceiver that allows you to operate up to six bands ranging from 10 meters to 1.2 GHz with one controller.

The IC-900 includes an ultra-compact remote controller for remote mounting, an Interface A unit, an Interface B unit, an SP-8 speaker, an HM-14 up/down DTMF microphone, plus fiber optic and controller cables.



Measuring only 1 × 2 × 5.7 inches, the remote control display can be installed on your car's dash or sun visor with supplied Velcro* strips. Simple to operate, it's equipped with a large LCD for easy viewing.

The IC-900 allows the operator to listen on two bands simultaneously or transmit on one band while receiving on another band (for true full duplex crossband operation.) All subaudible tones are built in, and the actual subaudible frequency is displayed. Ten memories are available for each band, with individual PL tone and offset programming capability.

Two scanning systems are available: programmable band scan and memory scan. Fiber optic technology enables a 3/16-inch cable to transport all data between Interface A (installed near the driver's seat) and Interface B (installed in trunk or rear of vehicle). Fiber optic cable also eliminates rf feedback.

Separate rf modules will be available for 10, 6, and 2 meters, and 135, 75, and 25 cm.

For information, contact ICOM America, Inc., 2380 116th Avenue N.E., P.O. Box C-90029, Bellvue, Washington 98009-9029.

Circle #305 on Reader Service Card.

repeater controller upgrades

ACC has announced two new upgrades for the RC-85 repeater controller.

Version 3 Firmware nearly triples the synthesized speech vocabulary to almost 500 words, making it easier to remotely program useful ID, tail, and bulletin board messages. A Kenwood TS-711A or TS-811A transceiver may now function as a synthesized remote base transceiver, with control through its serial port; support of these transceivers simplifies adding a remote base to the repeater system.

Many additional enhancements such as patch redial, more macro sets, zero hang time mode are included. The price is $125.00.

The AD-1 Audio Delay Line board provides a 75-ms audio delay from the repeater receiver to the transmitter. The benefits are squelch tail muting and complete touchtone muting through the repeater, resulting in pleasing repeater audio. The audio delay feature, an innovation ACC introduced in the RC-850 controller, is now available as an option for the RC85, priced at $150.00.

For additional information, contact Advanced Computer Controls, Inc., 2356 Walsh Avenue, Santa Clara, California 95051.

Circle #308 on Reader Service Card.

multimode TNC

The new Heathkit HK-232 Pack-Kit™ Multi-Mode TNC kit — a versatile addition to Heath's expanding Amateur Radio line — takes the hassle out of getting into RTTY, lets users run CW at speeds from 5 to 99 wpm and works on AMTOR, ASCII, hf, and VHF Packet. It decodes Weather Facsimile pictures onto Epson-compatible printers. The Multi-Mode TNC works Packet in both HF (300 baud) and VHF (1200 baud or up to 9600 baud, with an external modem.)

Adding the HK-232 to a radio and computer lets the Amateur get on the air in every mode. It connects to the radio's PTT line, speaker output, and microphone input for interchangeable VHF and HF operation. The same connections work for all other modes including CW.

Amateurs can connect both their hf and VHF rigs at the same time, to allow switching between VHF Packet and copying a WIAW RTTY bulletin on 40 meters with just the push of a button.

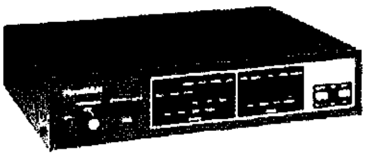
A unique "SIGNAL" command causes the Pack-Kit to determine the correct RTTY, ASCII, or AMTOR mode for the signal the Amateur is

listening to. It also presets baud rate and mode and will invert the signal if necessary. All the user does is type "OK."

The HK-232 even handles American Standard Baudot (Western Union), Japanese Katakana Morse, Cyrillic (Russian) Morse, and translated versions of Cyrillic and Katakana.

The Pack-Kit will copy signals that seemingly baffle other units. The HK-232 features an eight pole audio bypass filter followed by a limiter discriminator with automatic threshold correction.

No special software is required to operate the HK-232 Pack-Kit TNC. It can be used with any modem communication package you may already have or an optional program written specifically for the HK-232 and a Heathkit/Zenith PC or PC-compatible computer. It connects to a terminal or computer through a standard RS-232 serial port at baud rates from 300 to 9600. A step-by-step, easy-to-understand Operation Manual is included.



For more information, send for a free copy of the Heathkit Catalog: contact Heath Company, Department 150-945, Benton Harbor, Michigan 49022. (In Canada, contact Heath Company, 1020 Islington Avenue, Department 3100, Toronto, Ontario, M8Z 5Z3.

Circle #301 on Reader Service Card.

trap antennas

Spi-Ro Manufacturing offers a complete line of both dipole and vertical "sloper" multi-band trap antennas that cover all Amateur bands from 10 through 160 meters.

The lightweight, sealed, and weatherproofed traps feature rustproof solid brass terminals that require no soldering or jumper wires. Easy to install in the field, they handle full power, and allow users to work multiple bands with a single antenna. They're suitable for all transmitters, transceivers, and receivers, and are fed with coax via a standard PL-259 connector.

For more information, contact Spi-Ro Manufacturing, Inc., P.O. Box 1538, Hendersonville, North Carolina 28793.

Circle #309 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance.** No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (not all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

ANALOG AND RF CONSULTING for the San Francisco Bay area. James Long, Ph D N6YB (408) 733-8329

TEST EQUIPMENT WANTED. Don't wait — we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn N7EPK, at Skagitronics Co. (800) 356-TRON

"HAMLOG" COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7-band WAS DXCC. Full features. Apple $19.95 IBM or CP/M $24.95. KA1AWH POB 2015, Peabody, MA 01960

RV OPERATORS are invited to check in Sun 2 PMC, 14.240 ± 5. Tues. Thurs 8 PMC 3.880 ± 5. Good Sam RV Net. Info SASE KJ4RO

FREE HAM CATALOG. SASE. Barr, 2549 H6 Temple, Palm bay, FL 32905

HOMEBREW PROJECTS. SASE. W62EUF, Box 708, East Hampton, NY 11937

YAESU FT-727-R COMPUTER INTERFACE. For info write Gerald Hogsett Consulting, 1581 Woodland, Palo Alto, CA 94303

TEN-TEC CORSAIR Model 560 with 280 power supply additional 2nd 8 pole 2.4 KC filter plus 1.8 KC and 500 Hz filters $845 w/shipping. AEA PK 64 w/HF modem, w/shipping $130. MFJ Versa Tuner V Mod 989, 3 KW w/shipping $145. All items mint condition. Richard B. Stevens, W1OWJ, POB 118, Ashuelot, NH 03441 (603) 239 6079

EIMAC 8877 less than 10 hours use with filament transformer $330 shipped. Richard B. Stevens, W1OSJ, POB 118, Ashuelot, NH 03441.

COMMODORE REPAIR. We are the largest/oldest Authorized Service Center in the country (ex. C64-$39.95), 72 hour turnaround. Call Toll Free 1-800 642-7634 (outside NY) 914 356-3131. Kasara Microsystems, Inc., 33 Murray Hill Drive, Spring Valley, NY 10977

COMMODORE CUSTOM CHIPS for C64/128 Computer Peripherals at low prices. 24-hour delivery #6510-$9.95 #6526-$9.95, #6567-$14.75, #6581-$12.85, PLA $10.95, 901 ROMS at $10.95 each, C128 ROMS-$39.95 (set of 3) and many others "THE COMMODORE DIAGNOSTICIAN". A complete diagnostic reference chart for fixing Commodore computers, etc. An absolute must for those who want to fix their own computers and save money and down time. $6.95 plus postage. HD Power Supply for C64 $27.95. Send for complete chips/parts catalog. Kasara Microsystems, Inc., 33 Murray Hill Drive, Spring Valley, NY 10977. 800-248-2983 (outside NY) or 914 356-3131

CODE PROGRAMS. APPLE/C-64. 37 modes. LARESCO, POB 2018, 1200 Ring Road, Calumet City, IL 60409. 1-312-891-3279

FREE SELL-WANT LIST. WA6GER, 3241 Eastwood Rd, Sacramento, CA 95821.

FOR SALE: Yaesu FT-101EE, CW filter, desk mic, cover, manual, original box, excellent condition. Upgrading. $550. Matt Tyszka, 129 West Rd, Collinsville, CT 06022. (203) 693-0468 (WA1RRE).

WANTED: External Frequency Display YC-7B for Yaesu FT7B. W4YKH "Bill". Call collect (703) 533-0359.

DENTRON RADIO COMPANY—*The New Dentron Radio Company*. Replacement parts, technical information, new products. We will service any Dentron Radio products. Models Clipperton L, MLA 2500, Gla1000 series, MT3000A, MLA1200, DTR2000, DTR1200L, MT2000A or any Dentron Radio product. Please call or write. We will do our best to serve you. Dentron Radio Company, Inc, PO Box H, East Rockaway, New York 11518. Call (516) 536-2620.

23CM FM TV. Full line of modules. Tactical Electronics, PO Box 1743, Melbourne, FL 32902.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

SLEP SPECIALS: Jennings UCSL 1000 vacuum variable capacitors 10 thru 1000 MMFD at 5000V with gear drive train and mounting bracket. Ideal for that linear amplifier or tuner $69.50. Plate transformers Genset P/N 271-107 for models 903, 913A 2/6M VHF linear amplifier using 4X150A, 4CX250B, 1650 VDC at 400 MA size inches 5 1/4L x 4 1/2W x 4 1/4H for replacement or amplifier construction $37.00. HP805B slotted line 500 MHz thru 4 GHz $275.00, HP8640B 500 kHz - 1024 MHz $5,500.00. Tektronix 545B oscilloscope with CA dual trace plug in $375.00. TS 510A signal generator 10 MHz-420 MHz military version of HP608D $275.00. HP606A signal generator 50 kHz thru 65 MHz $375.00. Have quantity all items, satisfaction guaranteed. VISA, M/C or check. Add shipping. Phone Bill Slep (704) 524-7519. Slep Electronics Company, Highway 441, Otto, NC 28763.

MEASURE VSWR, antenna patterns, match circuit impedances from 100 kHz to 2 GHz with portable scalar network analyzers. Write for details. Direct Conversion Technique, 3132 North Lowel Avenue, Chicago, Illinois 60641. (312) 283-1690.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117 (203) 521-5280.

ENGINEERS request free catalog of Electronic Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252

REMEMBER TROLLEY CARS? *Trolley Treasures: The War time Years in New Jersey* (1939-1947), a 4-volume photodocumentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport* ready now. SASE for details. To order, contact Trolley Themes, A.W. Vankoff, 2237-3 Woodside Lane, Sacramento, CA 95825 ($14.95 plus $1.50 S&H)

$$$$$SUPER SAVINGS on electronic parts, components, supplies and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD ELECTRO, PO Box 830119, Richardson, TX 75083 or call (214) 690-1102.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510

WANTED Manuals and Cables for type RBM-2 Rcvr, June 1942 and CCT 20086 power unit. D. Palmer, W6PHF, 638 Benvenue Avenue, Los Altos, CA 94022.

BACK ISSUES HR Magazine from Vol 1 No. 1 thru 1986, except 2 issues. $150 for all postpaid. Also PopTronics, RE, 73 back to 1961. $15.00/full year. Write with your needs. Bill Fossman, 632 Wetmore, Everett, WA 98203

CANTENNA NEW $20.00 1 kw. Ham Keyer model HK5A new $40.00. Roller inductors, Johnson and B W. $20.00 each. M C Jones power meter 1 kw with coupler $20.00, new 813 transmitting tubes $20.00 each. C E 100V exciter $170.00, 75S3 receiver $175.00. Collins. Brown Simpson MK 75 memory electronic keyer $125.00 mint. Near new Gonset GSB 100 $125.00. Eldico 100F exciter $150.00, miniature tubes $1.00 each, octals loctals $2.00 each. Levy, W5QJT, 2833 Junction Hwy No. 15, Kerrville, TX 78028 (512) 367-4741

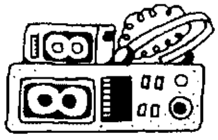
MARCO: *Medical Amateur Radio Council, Ltd,* operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc) invited to join. Presently over 550 members. For information write MARCO, Box 73's, Acme, PA 15610.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave . . . all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.



COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

CONNECTICUT: November 15. SCARA Indoor Ham Radio and Computer Flea Market, N. Haven Park and Recreation Center, 7 Linsley St, N. Haven. Sellers admitted at 7 AM; buyers from 9 AM to 3 PM. Tables are $10 in advance, $15 at the door. General admission $2 per person. Talkin on 146.61 MHz. Reservations for tables must be prepaid by November 4, 1987 and no reservation by phone. For information or reservations SASE to: SCARA, *POB 81, N. Haven, CT 06473 or call Brad at (203)* 265-6478 between 7 PM and 10PM

INDIANA: November 8. The Allen County Amateur radio technical society presents its 16th annual Fort Wayne Hamfest. Allen County Memorial Coliseum, Coliseum Blvd. 8 AM to 4 PM. General admission $3.50/advance; $4.00/door. Children 11 and under free. VE exams November 7 by advance registration only. Forums. Other activities. Nearby motels and restaurants. For more information or reservations contact ACARTS Hamfest, POB 10342, Fort Wayne, IN 46851. For information ONLY Bernie Helm, K9JDF, Hamfest Chairman (219) 485-0164, 6 to 10 PM EST

OKLAHOMA: October 4. Salt Plains ARC Eyeball QSO Party south side of *Salt Plains Lake, North Central Oklahoma. Talk* in on 147.30/.90 or call Gary Gerber, KB0HH (316) 842-5079 or 842-5155

ILLINOIS: October 31 and November 1. The Fox River Radio League is sponsoring the ARRL's Central Division Convention as part of a *Hamtastic Weekend. Norris Sports Center* at Rt 64 in St. Charles, about 35 miles west of Chicago. 8 AM to 2 PM both days. Tickets $3.00/advance, $4.00 door good for both days. Indoor flea market, forums, *seminars* and tech demos. Exams for all license classes. For advance tickets or information on tables or exams contact Phil Fors, N9FXC, 104 May Street, West Chicago, IL 60185 (312) 231-3841. SASE appreciated. Talk in on 145.47 (-600) and 146.21 (-600)

ILLINOIS: November 1. The Waukegan CAP will hold its 7th annual Hamfest. Lake County Fairgrounds, Rts 120 and 45, Grayslake. 7 Am to 5 PM. Large indoor flea market, cafeteria, *free parking.* Tables $5.00. Donation $3.00. For information and reservations SASE to CAP, 637 Emerald Street, Mundelein, IL 60060

MINNESOTA: October 31. The third annual Hamfest Minnesota and Computer Expo, sponsored by the Twin City FM Club, Hennepin Technical Center, North Campus, 9000 Brooklyn Blvd, Brooklyn Park. 7:30 AM to 3:00 PM. Admission $3.50/advance, $4.50/door. Guest speakers Tony England, W0ORE and Doug Clapp. New CW contest. FCC exams, giant indoor flea market and much more! Talk in on 16/76. For information or registration SASE to Hamfest Minnesota and Computer Expo, Box 726, St. Louis Park, MN 55426

NEW YORK: October 17. The Radio Amateurs of Greater Syracuse will hold their 32nd Hamfest, Arts and Home Center, New York State Fairgrounds. Giant indoor Flea Market, tech talks, contests, entertainment. Programs for non hams. Tailgating area

$3.00/car. Indoor flea market table $6.00 furnished. General admission $4.00. Under 12 free. FCC walk in exams start 12 noon. Novice through Extra. Talk in on 146.31/91 and 147.90/30. For information call Ed Swiatlowski, WA2URK (315) 487-3417 of Viv Douglas, WA2PUU (315) 469-0590 or write RAGS, POB ;88, Liverpool, NY 13088.

OHIO: October 25. The Marion ARC will hold its 13th annual Heart of Ohio Ham Fiesta, Marion County Fairgrounds Coliseum. 0800 to 1600 hours. Tickets $3/advance; $4/door. Tables $5. Check in on 146.52 or 147.90/30. For information, tickets or tables contact Ed Margraff, KD8OC, 1989 Weiss Avenue, Marion, Ohio 43302 (614) 382-2608.

ARIZONA: October 3. The Cochise ARA will hold its annual Swapmeet at the Club's Training Facility on Moson Road, Sierra Vista. Talk in on 146.16/.76. No charge for tailgaters. Refreshments available. For information: Jacquie Kelly, KD7DZ (602) 458-4107 or write CARA, POB 1855, Sierra Vista, AZ 85636.

OKLAHOMA: October 24-25. Texoma Hamarama '87, Lake Texoma Lodge, Catfish Bay, east of Kingston. ARRL programs, non-ham programs, Amateur exams, indoor/outdoor flea markets and more. Banquet, entertainment and dancing. For additional information contact: Texoma Hamarama Association, POB 610892, DFW Airport, TX 75261.

NEW YORK: October 18. Raindate October 25. NYC Largest Hamfest sponsored by the Hall of Science ARC, Hall of Science parking lot, 47th Avenue and 111th Street, Flushing Meadow Park, Queens. 9 AM to 3 PM. Buyers donation $3.00; Sellers $5.00. Computers, Amateur Radio, ARRL info, dealers. Visit the newly reopened Hall of Science museum and HOSARC's ARA WB2JSM. For more information call evenings only Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schiffman, WB2YXB (718) 343-0172.

TENNESSEE: October 24-25. The 9th annual Chattanooga Amateur Radio and Computer Convention, Grand Central Station at Chattanooga Choo-Choo complex. Amateur exams Saturday and Sunday. All forms should be sent to Hamfest Chattanooga, POB 3377, Chattanooga, TN 37404 by October 20. 8' flea market tables $10/day or $15/weekend. Talk in on 146.19/79. For further information write Hamfest Chattanooga, POB 3377, Chattanooga, TN 37404. Exhibitor info call WA4RMC (615) 892-8889. Flea Market info call KB4RTM (615) 622-8467 after 6 PM or W4ECW (615) 698-2147.

OHIO: October 11. NOARC (Northwest Ohio ARC) will hold their annual Allen County Hamfest, Allen Cluty Fairgrounds, Lima. Tickets $3.00/advance, $3.50/door. Tables $6.00 full; $3.50 half. License exams. Free camping available. Elec. $7.00. Talk in on 146.67 and 146.52. For info about exams W8TY, NOARC, Box 211, Lima OH 45802.

TENNESSEE: October 17. The 7th annual Tri-Cities Hamfest, Appalachian Fairgrounds, Gray. Indoor/outdoor flea market. Forums, dealers, RV hookups. Talk in on 146.37/97 and 146/01/.61. For information write Tri Cities Hamfest, POB 3682 CRS, Johnson City, TN 37602.

MASSACHUSETTS: October 25. The Framingham Amateur Radio Association's annual Fall Flea Market and Exams, Framingham Civic League Building, 214 Concord Street, Downtown Framingham. *Doors open 10 AM. Sellers setup 8:30.* Admission $2.00. Tables $10 includes one admission. Talk in on 75/15 repeater. For tables Jon Weiner, K1VVC, 52 Overlook Drive, Framingham, MA 01701 (617) 877-7166. For exams send Form 610, copy of license and $4.35 check to FARA, POB 3005, Framingham, MA 01701.

PENNSYLVANIA: November 1. The RF Hill ARC's 1987 Hamfest, Pennsylvania National Guard Armory, PA Rt 152, Sellersville. Doors open 6 AM for sellers, 8 Am for general public. Entry $4.00, accompanying spouse and kids free. 6'x 8' indoor space $8. Outdoors $6. Talk in on repeaters at 145.31, 145.19, 146.88 and 146.52. To reserve space write Hamfest Chairman, 523 Vine street, Perkasie, PA 18944.

MICHIGAN: October 25. The Southwest Michigan AR Team and the Kalamazoo ARC are sponsoring the 5th annual Kalamazoo Hamfest. New larger location: Kalamazoo Central High School, 2432 N. Drake Road. 8 AM to 4 PM. Walk in VE testing. Admission $2/advance, $3/door. Tables $6. Send requests and check with SASE by September 28 to Jim Hastings, Kalamazoo Hamfest, 1813 Greenbriar Drive, Kalamazoo, MI 49008.

OPERATING EVENTS

"Things to do . . ."

October 17-18: 30th Scout Jamboree on the Air. Active Scouts, former Scouts, Amateur Radio Operators; any and all who are interested in doing a good turn for Scouting and Amateur Radio.

October 4. The Fresno ARC emergency communications van will operate from the City of Clovis to help celebrate their Octoberfest Crafts Fair Pioneers' Day. 1500Z Oct. 3 to 0100Z Oct. 4. Listen for W6TO, the Diamond Jubilee Special Event Station. For certificate, QSL, large SASE to W6TO F.A.R.C., POB 783, Fresno, CA 93712-0783.

October 10-11: The South TexasAmateur Repeater Society (STARS) will operate N5CAF, 1400Z-2300Z to commemorate the annual Confederate Air Force Airshow held in Harlingen, TX. For special certificate QSL and SASE to Dr. David Woolweaver, K5RAV, 2210 S. 77 Sunshine Strip, Harlingen, TX 78550.

October 17-18: The Edmond ARS, a Special Service Club, will operate W5ERY from 1700Z to 1700Z in celebration of its 30th anniversary as an Amateur Radio club. Members will operate from the shores of beautiful Lake Arcadia. For a certificate send 9x12 SASE, 39 cents postage, to Edith Vaughn, KA5YPX, 1020 Juno Circle, Edmond, OK 73034.

HAM EXAMS: The MIT UFH Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday October 21, 7 PM, MIT Room 1-150, 77 Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 646-1641. Exam fee $4.25. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

short circuits

high-performance Yagis

In **fig. 11** of K1FO's July, 1987, article, "High Performance Yagis for 432 MHz," a dimension is incorrectly placed. In the upper right hand part of the figure, the dimension "2 5/16" should be moved to the right, to indicate the distance between the end of the T-match section and the end of the driven element.

ladder networks

The following information was omitted from **fig. 2** of W3NQN's article, "BASIC Program Analyzes Simple Ladder Networks" (August, 1987, page 34):

RS = RL = 50 ohms
C1 = C5 = 1100 pF
C3 = 560 pF
L2 = L4 = 1.75 μH

Fco = 3.37 MHz
F 3 dB = 2.74 MHz
F 20 dB = 1.97 MHz
F 40 dB = 1.32 MHz

wrong call

In **table 3** of W1JR's column in the July, 1987 issue, the call "WA5CIW/5," listed under 5760 MHz, should be corrected to read "WA5ICW/5."

SSTV with C-64

The address of the Journal of the Environmental Satellite Users' Group was shown incorrectly in the October article, "Get on SSTV with the C-64" (page 43). The correct address is 2512 Arch Street, Tampa, Florida 33607. (Tnx WD4MRJ)

Yaesu FRG9600 modification

A complete kit — or circuit boards alone — for the modification described in W6MGI's article, *"Add General Coverage to Yaesu's Latest VHF/UHF Receiver"* (October, 1985, page 67) is available from Radiokit, P.O. Box 411H, Greenville, NH 03048. The kit is priced at $89.95 plus $3.00 shipping and handling; the boards only, at $7.00 plus $1.25 shipping and handling.

ham radio

ELMER'S NOTEBOOK

Tom McMullen, W1SL

packet communications

The answer is "definitely *not*!"

The question is "Is this guy hung up on digital stuff, or what?"

Hung up on digital stuff? No. But enthused? Absolutely! You see, I'm a follower of the old adage that there's no such thing as too much knowledge. I've never learned anything that I haven't found useful at one time or another, so I'm all for grabbing any knowledge I'm capable of absorbing. (And it's surprising how much you retain, even when you think you're in over your head.)

At the same time, however, I realize that not everyone shares my enthusiasm for "all things, great and small." Hence my opening answer to questions that might come up about subjects covered in pursuit of the goals of this column. As stated originally (June, 1987), the purpose of Elmer's Notebook is, first, to address the immediate needs of Elmers, Novices, and anyone else coping with the "Novice Enhancement" rules change; and second, to continue with as many subjects as needed to help Novices (or anyone else, for that matter) upgrade to a higher class of license or simply *enjoy Amateur Radio more.*

Along these lines, I'll cover whatever topics I think will be useful. (I'm certainly open to suggestions.) So if a particular column doesn't fit into your concept of what Amateur Radio means to you, read it anyway so you'll have something filed away as "Maybe Useful – Someday." Hang in there – I'll get to your favorite subject sometime, especially if you'll tell me what it is! Now, let's take a look at packet radio.

what's a packet?

According to some dictionaries, a packet is "a small package that contains anything. . . ."[1] An electronics dictionary defines a packet as "a group of binary digits, including data and control elements, which is switched and transmitted as a composite whole."[2]

Though both definitions apply to Amateur packet radio in a general way, let's see if we can be more specific without letting the technicalities overwhelm us. Describing a packet as "a package that contains data and control elements" sounds good, but isn't that what RTTY, voice, and CW messages are? After all, they include the information to be transferred (the message), the control information (the address for delivery, the identification of the sender, and a word count for checking accuracy). The answer, then, is "Yes, but. . . ."

The rapid growth of packet radio began with a coincidence of timing that placed the newly popular personal computer within reach of many enthusiasts and the relaxing or rewriting of Amateur rules to allow data communications of greater bandwidths on the VHF and UHF bands (increased bandwidths allow higher speed communications). It doesn't really matter which mode you're using if you're limited to a top speed of 100 baud or so on the hf bands; RTTY, AMTOR, and ASCII can handle that speed with ease. The higher speeds permitted on 2 meters and above were attractive, but the need for something better than the digital modes used on the lower bands was obvious. For one thing, RTTY and its cousins had no provision for rapid automatic relaying of data if there wasn't a direct path between the originator and the destination. The instructions required to do this (called "overhead") could end up longer than the text that was to be sent.

In their search for better means of transferring data between computers at scattered locations, commercial developers devised systems that provide fast, accurate transfer of data via telephone links, cable systems, and/or microwave or satellite relays. They're not only accurate and fast; they're *transparent* to the user – i.e., you feed your message into the system, and the system does the rest. Networks and repeaters are also accommodated in the language of these systems.

Such systems and languages are called *protocols*. "Protocol" means the same thing in packet radio as it does in any other context; it's a set of prearranged operating procedures, signals, and language that make sure you understand precisely how I'm going to say something, what I mean when I say it that way, and how you should respond when I say it. As long as we both stick to the protocol, the chance for misunderstanding (i.e., errors) is small.

One very successful digital protocol

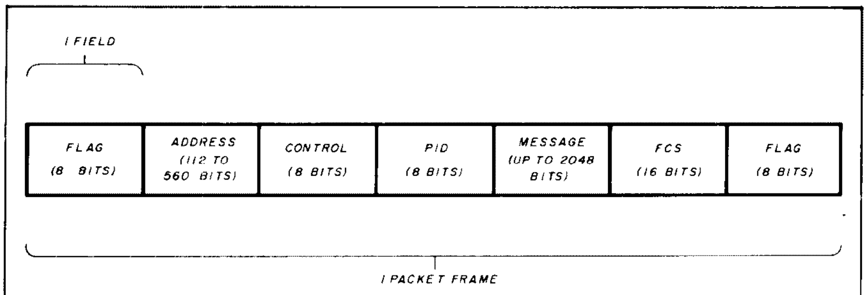


fig. 1. The AX.25 packet protocol frame is made up of several fields, each with a specific number of bits that convey special information about operation. This is an information frame. Supervisory frames, used to control links or repeaters, are similar but do not contain the message field.

is called High-level Data Link Control, or HDLC. Obviously, you don't have to know all about HDLC or the other protocols used to enjoy packet radio, but a basic understanding will help you see how it all fits together. (Beside, sooner or later you'll start wondering, "How do they do that?")

HDLC is part of a broader protocol called X.25, which covers several "layers" of packet radio, from the local level up through several types of networks. I'll not go into the history of how Amateurs got packet radio going, except to say that several individuals and organizations realized that a standard was needed if packet was to become more than a curiosity. As a result of a series of conferences, the X.25 protocol was adopted, with some minor modifications, as AX.25 (the A is for Amateur, obviously). Predictably, once a standard was established, the mode — and the equipment industry to supply it — mushroomed. (If you're interested in more information about the birth and development of growth of packet radio, see "for further reading," at the end of this column.)

The Amateur packet radio protocol isn't really very complex (see **fig. 1**). Each packet frame is made up of well-defined sections called *fields*. Each has a specific job to do, as defined by the protocol.

The first field is a *flag*. In digital language, a flag is an arrangement of bits that attract the attention of the data-processing equipment. In AX.25, the protocol tells the sending equipment, "When you want to get the other guy's attention, send eight bits arranged in this manner (01111110)." The receiving station has been told, "Every time you see eight bits arranged in this particular pattern, pay attention!"

The rest of the packet is checked to make sure that this pattern never occurs anywhere except at the start or end of a packet. What the first flag says, in essence, then, is "This is the start of a packet."

Next is an *address field*, which contains both the identification of the originator and the destination. One of the nice features of AX.25 is that it recognizes Amateur call signs as proper addresses.

The third field presents *control information*. Control information can vary, depending upon the job it has to perform, but the most common types in this field include information for the user, supervisory information for controlling data flow, and "unnumbered" information for controlling the link (if any).

Next is a *protocol identifier field* (PID) that identifies the network-layer protocol being used (if any).

Then comes the *information or message field*. This is where your "Having a great time, wish you were here" message goes. There's room for 2048 bits in this field, but you don't have to use all of them. Most of the packets I've seen consist of two to three lines of text on a normal computer screen. Each line requires approximately 640 bits for an 80-character-wide screen, so a three-line packet message would use up to 1920 bits.

The field following the message is a *frame check sequence* (FCS). (Didn't I warn you that packet radio was loaded with "alphabet soup"?) The FCS tests the message for accuracy. It doesn't care if you misspelled or mistyped a word; it simply checks to confirm that it received everything that was sent. This is done by a formula that I won't go into here, but the microprocessor in your TNC (terminal node controller)* knows all about it. Basically, the sending station calculates and sends a number and the receiving station performs the same calculation to see if it gets the same number. If it does, the receiving station sends an acknowledgment, or "ack"; if it doesn't, no acknowledgment is sent, and the sending station repeats the packet, saying, in essence, "I'm going to keep on doing this until you get it right!"

The last field is a flag that signifies "The End."

This sounds like heavy stuff, but the microprocessor handles it so fast that you don't even know it's happening. A packet passed between two Amateurs chatting via their keyboards can be sent and acknowledged in less than 1/4 second.

hooking it up

The output from the TNC is in the form of audio tones, which are applied to the modulator in the transmitter just as any other audio would be. The output from the receiver is also audio tones, which the TNC processes to provide binary digits (pulses) for the microprocessor.

Commercially available TNCs come equipped with instructions for connection to your computer, and cables

*A *terminal* is your keyboard and screen; a *node* is a connection point to a network or circuit; and the *controller* does just that — it controls the data flow by putting information into packets according to the protocol in use.

may or may not be supplied. If they're not, you can make or perhaps buy some that will do the job. Hookup is frequently just as simple as plugging the cable into the serial port of the computer and using software that makes your computer act like a dumb terminal.

On the radio end, it's as simple as applying audio and push-to-talk (PTT) connections to the microphone (or auxiliary) input for the transmitter, and then plugging a connector into the external speaker plug on the receiver. Connectors vary in size, so you may have to shop for the right size to fit your radio. Many packet controllers use a nine-pin connector for the audio output/input to and from the radio, so you'll have to connect the wires from the microphone input and speaker output to this connector. It's a good idea to provide a termination for the radio's speaker to provide impedance matching and prevent distortion. **Figure 2** shows one way of doing this.

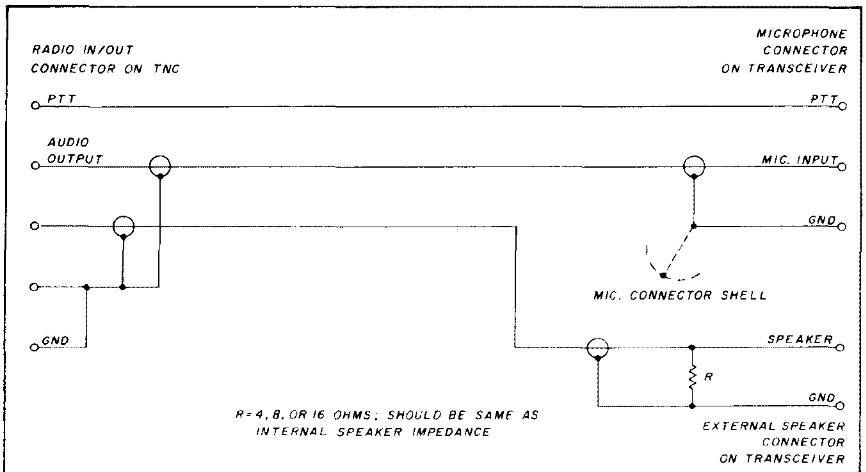


fig. 2. Typical connections between the TNC and radio equipment. Consult your TNC owner's manual for exact connector types and pin numbers to use.

what can I do with packet?

Packet is the fastest-growing mode of Amateur communication today, and more uses for it emerge all the time. In addition to just chatting with your nearby friends, you can send packets over *digipeaters* (digital repeaters) to distant stations (up to eight repeats can be handled by the packet protocol). You can perform public service at events or in emergencies; packet radio was used in the 1984 Summer Olympics in Los Angeles, in the field at forest fires in California, and in innumerable emergencies and emergency-preparedness drills nationwide. There are hundreds of packet bulletin boards (PBBS) throughout the country, and stations called "Gateways" that provide access to satellites and to UHF repeaters that increase the baud rate and allow rapid transfer of packet information over vast distances. Packet will also handle graphics, which opens even more possibilities!

what frequencies?

Like other digitial modes, packet can be used on 10 meters between 28.1 and 28.3 MHz. Novices can *listen*, but not operate, on several frequencies used on 2 meters; 145.01 MHz is the most popular, with 145.03, 145.05, 145.07, and 145.09 not far behind.

Several frequencies (223.42 to 223.90 MHz) on the 220-MHz band have been suggested for Novice packet operation. 223.30 has been suggested as a national packet simplex frequency (unless it's in use by a local repeater). Note that 223.50 is the national simplex frequency for voice fm, so don't use packet on that one.

Parts of the 220-MHz band have been used for developing experimental high-speed (9600 baud or higher) packet networking.

With Novice privileges now including packet on 220 MHz, the number of digipeaters and voice repeaters should increase, and local activity should grow rapidly. Check with local clubs for new activity in your area.

Here's a helpful tip for when you get your TNC hooked up and want to see things happening on your screen: set the Monitor Mode to ON. This will let you "read the mail" on the bands on which you can't transmit. Your instruction book will tell you how to do this — it's usually as simple as entering a command (usually MONON or MALL) from the keyboard.

This has been a thumbnail sketch of what makes packet radio an effective and entertaining mode. There's much left to tell, however, and I'll do that in a future column.

for further reading

The Amateur magazines have featured many excellent articles on packet radio. The following books contain a wealth of information about the development, operating techniques, and the future possibilities of this mode. All but *The Digital Novice*, which addresses several digital modes, are dedicated to packet radio; the first two are ideal for beginners in packet radio, regardless of license class. All are available from *ham radio's* Bookstore, Greenville, New Hampshire 03048.

The Packet Radio Handbook, by Jonathan L. Mayo, KR3T.

*Get ***CONNECTED to Packet Radio*, by Jim Grubbs, K9EI.

The Digital Novice, by Jim Grubbs, K9EI.

ARRL Computer Networking Conferences 1-4: Pioneer Papers on Packet Radio 1981-1985.

ARRL Fifth Computer Networking Conference Papers, 1986.

references

1. *The Random House Dictionary of the English Language*, College Edition, 1969.
2. *IEEE Standard Dictionary of Electrical and Electronics Terms*, IEEE Centennial Edition, 1984.

ham radio

NOVEMBER 1987 / $2.50

ham radio magazine

hr

focus on communications technology

annual RECEIVER issue

ham radio magazine

contents

NOVEMBER 1987

volume 20, number 11

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Europe (via KLM air mail), $37.00; effective January 1, 1988, $40.00
Canada, Japan, South Africa and other countries (via surface mail),
one year, $31.00; two years, $55.00; three years, $74.00

All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

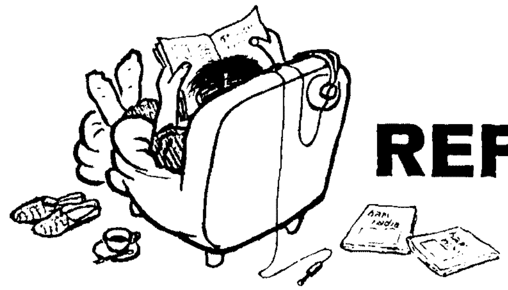
international subscription agents: page 99

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio* are available to the blind and physically handicapped from Recorded Periodicals, 919 Walnut Street, Philadelphia, Pennsylvania 19107

Second class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio* Greenville, New Hampshire 03048-0498



REFLECTIONS

specs in secs: an idea whose time has come

What's smaller than a bread box, *lighter than a Bic pen, faster than a speeding* bullet, and of interest to thousands of Radio Amateurs (or least it *will* be)?

You guessed it. It's Motorola's solution to our transistor specification problem, all on a single floppy disk. Appropriately labeled *Specs in Secs*, that's exactly what you get when you load it into your IBM PC-compatible computer.

In the program, Motorola has provided device information for over 1600 bipolar power transistors and TMOS™ Power MOSFETs, and included a user-friendly method of retrieving the data as well. It's not only extremely useful, but also fun to use. And because of its flexibility, you feel like you're making real design decisions — and you are!

Did I just hear someone say "Now just hold on one dang minute! We're Radio Amateurs, not engineers. Why do we need this information, anyway?"

I'm really glad you asked. First of all, some of us are engineers or technicians, in addition to being licensed Radio Amateurs. And even if you're not an engineer or a technician, I'm willing to bet that sometime in your Ham career you've designed some circuit, or at least wished that you could have. *Specs in Secs* won't do the circuit design for you (although there are software programs out there that will). What it will do is, through a few keystrokes, provide parts choices in *seconds*.

"Great!" you say, with a little bit of sarcasm. Now you have 1600 or so *power* device specifications. But like most other Radio Amateurs, you're interested in rf circuits — oscillators, preamplifiers, etc. Well, don't sell a power device short before you look at its specifications — f_T, for example, which is related to maximum frequency of operation. Some of these power devices provide real gain at frequencies that are of interest to us.

Without dwelling on this point, let me mention that Motorola indicated in the brochure that accompanied this diskette that they're working on *entering their entire semiconductor product* line on a single 360K floppy disk, and that takes time. I should know; I've done something similar with my compendium of Amateur Radio article references, *From Beverages Thru OSCAR — A Bibliography* (November 1980), and that only took me six years and eight diskettes, and I'm *almost* finished!

"But is *Specs in Secs* easy to use?" you ask.

It couldn't be simpler. You place the disk in any drive, type the letter M (Enter), and away you go. A menu provides a number of choices, including, in essence, an on-screen manual. Actually, the first thing you see is a "Start-up Screen" with a carefully chosen set of choices (defaults) that you'll probably want anyway.

Here's where it really becomes useful. Selection "D" is called "Parametric Search." With this choice, you're given the opportunity not only to choose the important parameters, but their order and value as well. The more specific you are, the more quickly you'll arrive at the appropriate component. Motorola does, however, recommend that you also have the hard copy (selection guide) available for the final decision-making process.

If you're reasonably sure of the component you want to use, just enter its part number after pressing Selection "C," appropriately labeled "Part Number Search." If it can't be found, you won't be hit over the head or knocked out of your chair by a loud noise. The program will just quietly tell you that it can't find that particular part number. Believe me, you still have many other choices.

I could easily go on about its other features, but for $2 you can get your own copy and see for yourself. By the way, Parlez-vous Francais? Or German, Spanish, or Italian? The on-screen manual is written in these other languages as well, and you can print all of them out and have a copy at your side.

For your copy of *Specs in Secs* (DK101/D), send a check or money order for $2 to Motorola Semiconductor *Products*, Literature Distribution Center, P.O. Box 20924, Phoenix, Arizona 85063.

Rich Rosen, K2RR
Editor-in-Chief

comments

Dick Smith kits

Dear HR:

Perhaps you've heard this, but in case not: I just found out that Dick Smith Electronics is no longer doing business in the United States. The Dick Smith kits are now being sold by American Electronics, P.O. Box 301, Greenwood, Indiana 46142.

Joe Moell, K0OV
Fullerton, California 92633

say what you think

Dear HR:

What a delightful guest editorial by Robert Zavrel, Jr., W7SX (September, 1987)! Nearly everything listed was something I could identify with. However, I had to move some of the "don't likes" into the "do likes" column, and vice versa. Not many, but some.

That started me thinking. Wouldn't it be interesting to see how other readers felt? As Bob said in the article, "there comes a time when a guy's got to say what he really thinks!" My mind started wandering. It would be really fun to see what men and women hams think about things! What about a checklist with an item per line, and a box for "Y" or "N" after each one?

Bob listed 28 "really don'ts" and 49 "really dos." That makes a total of 77 things to feel strongly about. I would like readers to send me their opinions on any or all of these 77 "reallys," either by mail or by packet BBS (KZ1O @ WB1DSW). The message could be kept short by just sending a 77-character long "opinion string" of Y's (like) and N's (don't like).

I'll tabulate the answers and send the results to *ham radio* magazine, because, as the last line of the editorial said I also like "magazines crazy enough to publish this."

That's what the last "Y" in my opinion string stands for:
YYNNNNYYNNNNNNNNNNNNNN
NNNNNNYYYYYYYYYNYYYYYYY
YYYYYYNYYYYYYYYYYYYYYYY
YYYYYYYY.

I'm looking forward to hearing from a lot of readers!

Dave Bushong, KZ1O
2 South Spring Street
Concord, NH 03301-2424

a word of caution

Dear HR:

Thank you for the article, "Solar Activity and the Earth's Magnetosphere," (August, 1987). It's very well written, and Bradley Wells is to be congratulated. For the layman, it answered many questions regarding the sun's relation to radio propagation. It also provided a good summary of the mechanics of the lines of magnetism.

There is one point I would like to bring to your attention, however. There are at least two instances where the phrase "may be visible to the naked eye" occur: on page 11, under the subhead "sunspots," and on page 13 under "flares."

At the risk of appearing overly cautious, it seemed to me that this implies that all one has to do is to gaze at the sun and these flares or sunspots would be apparent. However, readers who value their eyesight should be warned that "gazing" (my word) at the sun can be devastating. I'd therefore suggest a word of caution to the casual reader.

I hope there will be many more pieces about the sun; with the Solar year apparently coming out of its "dip," we could all benefit from a greater understanding of solar phenomena.

Rupert A. Wood, WB4ZOF
Bethesda, Maryland 20816-1760

tomorrow's receivers:
what will the next 20 years bring?

New techniques, technologies promise lower power, smaller size, higher performance

It seems that with each new issue of *ham radio* and other journals, we witness new technological developments affecting nearly every aspect of Amateur Radio. From time to time many of us ponder the questions, "Where is it all going?" and "What will rigs look like 10, 20, or more years from now?"

Predicting the effects of today's research on tomorrow's reality is always tricky business. But new techniques now in use in commercial and military radio systems are likely to find their way into Amateur applications sooner or later. I've discussed some of these techniques here, emphasizing what I see as their implications for Amateur Radio design.

Recent breakthroughs in technology may change some of the fundamental ground rules not only of radio engineering, but of electrical engineering in general. Consequently, two levels of development will be addressed here: first, those techniques in current use and second, those which may be possible in the near future.

Figure 1 shows a block diagram of a typical radio receiver. This is the familiar superheterodyne design, which has been predominant for nearly 60 years. Most commercial receivers on the market today use this same architecture — and in truth, there's been little improvement in radio performance for the past 30 years![1]

Other characteristics have certainly changed for the better, however: size, power consumption, 12-volt operation, frequency stability and accuracy, and ease of operation, for example. Yet the basic receiver functions remain the same; an rf signal down to the submicrovolt level must be amplified, converted, filtered, amplified again, demodulated, amplified again, and then converted into acoustic audio. There's nothing to suggest that the principle of rf input and audio output will change as a basic function for radio engineers. Rather, it's how you get from point A to point B that's undergoing a quiet revolution.

Perhaps the most striking developments have been in miniaturization. There's a continuous trend towards developing components with excellent specifications but with smaller sizes and lower power consumption.

rf amplifier

The first stage of a receiver largely determines the noise figure. Up to about 15 or 20 MHz, there's little advantage in using low-noise amplifiers because atmospheric and galactic noise are more significant than the noise figure of the typical first mixer stage. For this reason the preamp has actually disappeared from many hf receivers. Diode ring mixers typically have about a 7-dB noise figure, which is quite adequate for most hf receivers. The preamp also lowers the dynamic range of a receiver as it increases the rf level to the first mixer. At VHF and higher, the atmospheric noise drops and the receiver noise figure becomes one of the most important system specifications. At VHF frequencies and higher, the GaAsFET has dramatically reduced receiver noise figure specifications. This trend will continue as GaAs technology improves and prices decline.

first mixer

The most common rf mixer is the passive quad diode ring. It has a relatively low noise figure and the limitation to dynamic range is mainly a function of LO power used. A generalization can be made about the LO power necessary to handle a given rf power level: the ratio of maximum rf input power to minimum LO power is about 1:10. That is, for a diode mixer to handle 100 mW of rf, the LO power must be at least 1 watt.

By **Robert J. Zavrel, Jr., W7SX**, P.O. Box 23447, Tucson, Arizona 85734

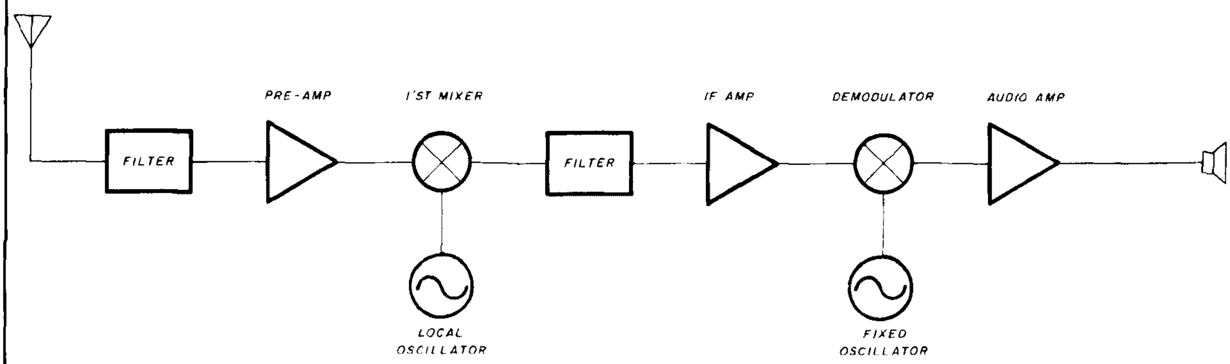


fig. 1. Typical present-day superheterodyne receiver.

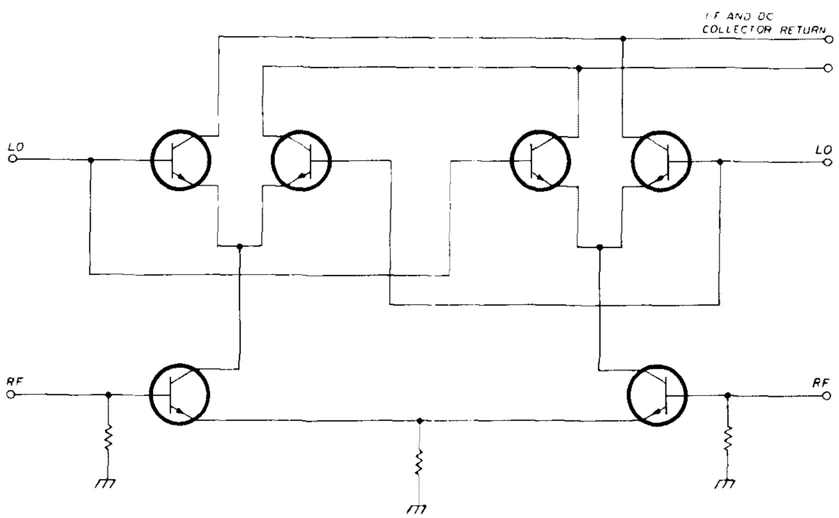


fig. 2. Gilbert Cell multiplier-mixer.

There have been two major developments in mixer technology during the past few years. The first is the passive FET ring, exemplified by the Siliconix Si8901. With this device, gate voltage rather than a forward-biasing current turns the switches "on" and "off." Since the gates represent high impedances, voltage/power ratios can be increased, thus lowering the LO power requirements dramatically. Indeed, to handle the same 100-mW rf power in our diode ring example, the Si8901 requires about 25 mW of LO power instead of the 1 watt mandated by the diode rings. The other critical specification is the third-order intercept point, which is necessary for defining the useful dynamic range. Again, the Si8901 greatly surpasses the old diode ring mixer.[2]

Working from the same empirical thinking that led to the development of the Si8901, a passive GaAsFET ring should surpass the performance of the silicon Si8901 by perhaps a 7-dB increase in third-order intercept point specification. Since the GaAs devices would be used as switching elements rather than active amplifiers, the 1/f noise limits of these devices wouldn't be an issue. They could be used at sub-audio frequencies with comparable noise performance at hf.

Although purported as a passive mixer, the Si8901 should also make an excellent active mixer. Using the same concepts as the old U350, the DMOS Si8901 should outperform its JFET cousin. The smaller geometry SD201 DMOS family made excellent VHF low-noise amplifiers before Signetics discontinued its DMOS line several years ago. Siliconix and the other DMOS manufacturers have chosen not to build these smaller devices, although both mixer and amplifier performance could be enhanced by such a modification.

As the world of digital integrated circuits has shifted its attention to faster CMOS technologies, advances in analog bipolar IC techniques have quietly proceeded. A fundamental bipolar mixer circuit is the

Gilbert Cell (**fig. 2**). Though the most familiar Gilbert Cell ICs are the Motorola MC1496 and MC1596, there are many manufacturers of these devices today. Over the past few years there have been several variations on this original commercial design. Good noise performance has been achieved with the Signetics NE602, but it can't handle the higher input levels necessary for good hf first mixer design. The NE602, however, is perhaps the finest mixer available among low power consumption mixers. Advances in bipolar processing are pushing noise figures down and power handling capabilities up in simulation models as well as in newly available devices. If this trend continues, the diode ring may become an endangered species.

local oscillator

Perhaps the most dramatic advances in receiver technology have been in the design of local oscillator circuitry. Very exotic mechanical assemblies evolved for LO tuning in the 1950s. (Remember the NC300, HQs, and Collins receivers?) Permeability tuned oscillators (PTOs) simplified things in the 1960s with the SB300, R4, and S-lines. Today, PTO LO performance remains difficult, if not impossible to duplicate with PLL synthesis, given the constraints of typical Amateur budgets. Synthesizers offer distinct advantages in that they can be directly controlled by microprocessors and don't require special mechanical rigidity or moving parts. A single crystal oscillator frequency is divided down to some low value and then "phase-locked" up to the desired LO frequency. At the output of the VCO, a multiple of the reference frequency equal to the reference frequency times the divider's "N" value appears (see **fig. 3**). This represents a simple phase-locked loop synthesizer, but it contains all the necessary building blocks of a more sophisticated system. If the reference is 1 kHz and the divider is set to N = 7005, the VCO output will be 7005 × 1 kHz, or 7.005 MHz. Discrete frequency steps of 1 kHz will be possible because only division by whole numbers is possible in this system. N determines the output frequency because the dc control voltage feedback will "lock" the VCO to the output frequency that provides equal frequency inputs to the phase detector.

Another type of synthesizer — the "direct digital synthesizer" or DDS — holds great promise. To understand how DDS works, two concepts must be understood: first, the concept of how digital-to-analog converters function and second, the Nyquist Theorem. I'll discuss each of these very briefly.

A digital-to-analog converter (DAC) takes a binary number and "converts" it into a discrete voltage or current value. An eight-bit DAC, for example, can have a maximum of 256 different voltage outputs. The digital eight-bit "word" can be generated by a microprocessor or memory circuit. A sine wave or any other waveform can be approximated by discrete steps as shown in **fig. 4**. For LO applications, sine wave approximation is preferred because sine waves have the lowest harmonic content. (A perfect sine wave will have no harmonic content.)

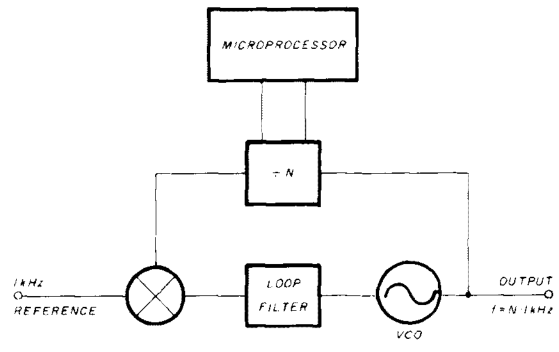


fig. 3. Simple digital PLL frequency synthesizer.

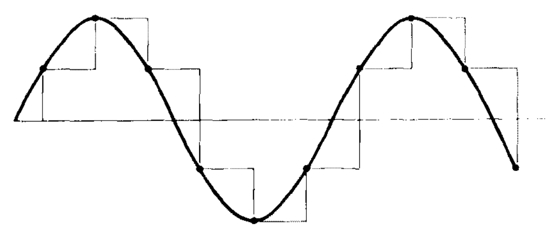


fig. 4. Sine wave digital approximation.

The Nyquist Theorem states that a sine wave can be derived if at least two discrete amplitude samples per period are obtained. Thus, if we want to synthesize a 5-MHz sine wave with a DDS, we'll need an updating clock rate of at least 10 MHz. With DDS, a constant sample rate can be used to synthesize any frequency up to half the sample rate with excellent frequency resolution (0.1 Hz typical). **Figure 5** shows how 1- and 2-MHz sine waves can be generated by a 10-MHz clock and a DAC. The microprocessor computes the values to be sequenced by the DAC for a given frequency output and a given clock rate. This special processing function is called a phase accumulator. Higher clock rates allow for more samples per period. More samples, in turn, allow for better approximation of the sine wave shape. Also, the greater number of bits allows for more discrete amplitude steps, which also enhance the accuracy of the sine wave approximation. DAC integral linearity affects waveform accuracy and harmonic levels. Indeed, the major efforts in DAC development are directed towards

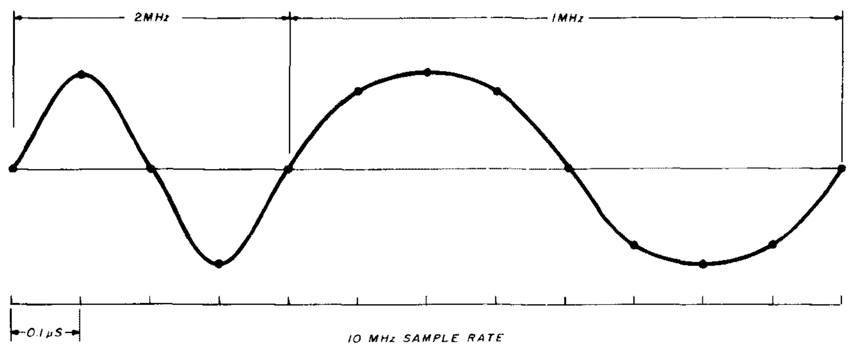


fig. 5. DDS sinewave synthesizer. Any frequency can be synthesized up to 1/2 the sample rate by changing the digital numerical value at each sample point.

better resolution (i.e., more bits) at higher update speeds. Off-the-shelf video-speed DACs now allow excellent performance for DDS circuits well into the hf spectrum. The Burr-Brown DAC63 is such a device. As DACs become faster and more accurate, the phase noise and harmonic performance improve.

Compared with PLL synthesizers, DDS offers other advantages. Since all the parameters of the waveform (frequency, amplitude, and phase) are digitally controlled, frequency hopping, or QSY, is almost *instantaneous*. PLL systems, on the other hand, have some finite settling time. In addition, nearly any type of modulation is possible if the applicable parameter is changed in accordance with a modulating waveform. Outstanding linearity is possible even at very wide bandwidths — in fm, for example.[3] To achieve the necessary low spectral noise densities demanded by hf LOs, more work is needed; however DDS holds great promise as a replacement for PLL synthesizers.

Figure 6 shows a direct conversion phasing SSB receiver. Traditional analog phase and amplitude nulling techniques employing all-pass active filters could yield 40-dB image rejection at best. The problem of this nulling is compounded by the need for broadband 90-degree phase shifters.[4] However, if we digitize the two signals the phase and amplitude nulling can be performed using a digital signal processor (DSP). Small errors in phase and amplitude can be removed

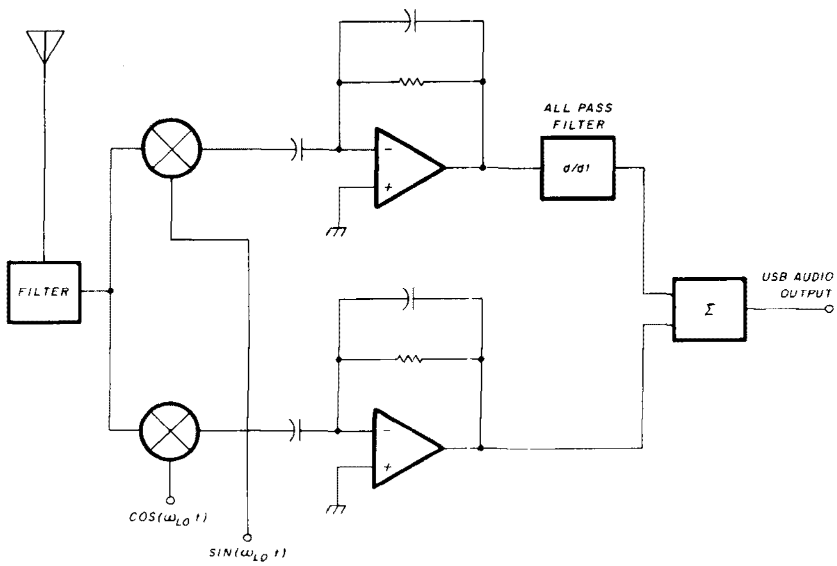


fig. 6. Direct conversion SSB receiver.

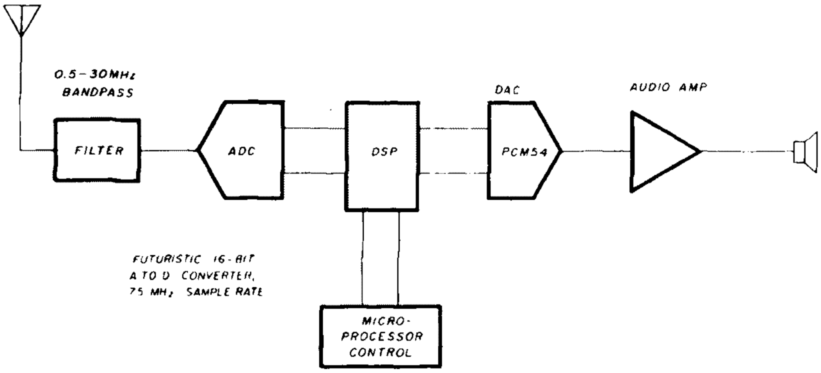


fig. 7. Digitized radio of tomorrow.

and the ultimate image rejection will correspond to the bit resolution of the analog-to-digital converter ADC. A 16-bit ADC, for example, could provide 96- dB image rejection using an ideal DSP. This would make an excellent receiver. Very sharp analog audio filters would be required before the ADCs. Philips has produced such a dual-channel filter in monolithic form, but it's not yet commercially available. More traditional upconversion schemes using DSP are discussed in an outstanding new textbook.[5]

Once the demodulated audio baseband signal is digitized, digital filtering techniques can be used. Very steep skirt notch and bandpass filters can be arranged. The amplitude coefficients can be manipulated to allow idealized audio AGC. Alternately, an AGC voltage can be provided through a DAC which controls an rf stage gain. Finally, the digitized audio can be converted back into analog form via a DAC, in much the same way as compact disc players function. The Burr-Brown PCM54 is an excellent 16-bit DAC for this application.

Figure 7 represents a daydream of where radio engineering state of the art might be within 20 or 30 years. A bandpass filter from 0.5 to 30 MHz tunes the entire hf spectrum. A futuristic 16-bit ADC with a 75-MHz sampling rate provides a 96-dB dynamic range over the bandwidth. The entire spectrum is digitized. All filtering, demodulation, AGC, and such, is performed in the rather sophisticated DSP. A PCM54 is then used to output the audio to an audio amplifier.

superconductors

In April the news media reported that a group working at an IBM facility in Switzerland had developed a new material that remains a superconductor up to 85 degrees K. This material, by itself, makes superconductors possible at liquid nitrogen temperatures, thus dramatically lowering the costs of using this class of material. Perhaps of far greater importance is that this work represents a crucial breakthrough for creating better superconducting materials. There is even talk of superconductors at room temperatures. What can this mean?

Superconductors are created when a material is cooled down to a critical temperature. Below the critical temperature the material exhibits *zero* electrical resistance. When superconductor offers literally no resistance at room temperature, electronic device technology could advance dramatically. Josephson junction or SQUID digital circuits could render even the fastest computers now available obsolete. For analog and rf circuits, zero resistance could have great implications for speed and noise specifications. Thermal noise disappears in superconductors as $V^2 = 4KTRB$. Never mind Boltzman; R is now zero. With zero resistance, charge mobility — a limiting factor for the speed of any semiconductor material — becomes quite high.

With superconductors, storage "battery" technology would be revolutionized. Imagine an electromagnetic car battery the size and weight of a donut! Charging efficiency would approach 100 percent.

Superconducting antennas and transmission lines would improve efficiency and lower system noise figures. Can you imagine 160-meter loading coils with zero resistence?

This is the most exciting development in solid-state physics since the invention of the transistor. The implications may by far outweigh the transistor's effects on the world. Electronic and electrical power engineers will have to rewrite all the books — again.

what to watch for

The radio art is in constant evolution. Here are some of the trends to watch for between now and the advent of the twenty-first century:

- Continued miniaturization of all components, thanks to higher levels of circuit integration and advances in wafer processing techniques.
- Lower supply voltage and current requirements for

comparable performance and improved performance, generally among all building-block components.

- Increased use of digital techniques in LO circuitry, and use of DSP for filtering, demodulation, and other functions.
- Appearance of data conversion devices, first at baseband, then at the i-f, and then moving closer to the antenna circuitry.
- Dick Tracy's two-way wrist radio will become a reality by 1995.

Putting predictions into print preserves the prophet's prognostications for posterity. It might be amusing, in the year 2007, to dust off your yellowed, musty copy of this issue to see just how far off the mark we were. Happy dreams!

references

1. Doug DeMaw, W1FB, and Wes Hayward, W7ZOI, "Modern Receivers and Transceivers: What Ails Them?", *QST*, January, 1983.
2. Ed Oxner, "Designing a Super-High Dynamic Range Double-Balanced Mixer," Siliconix Applications Note, revised October, 1986.
3. Earl McCune, "Direct Digital Synthesis and the Numerically Controlled, Modulated Oscillator," *Digital RF Solutions*, proceedings of the RF Technology Expo, February, 1987.
4. Robert J. Zavrel Jr., "ICs Simplify Design of Single-Sideband Receivers," *EDN*, April 3, 1986.
5. William E. Sabin and Edgar O. Schoenike, *Single-Sideband Systems and Circuits*, McGraw-Hill, 1987.

ham radio

designing a state-of-the-art receiver

Readily understood — though not greatly utilized — concepts mean better performance

The state of the art in hf receiver design using semiconductors has improved greatly. The use of either CATV-type transistors and double-balanced mixers using hot carrier diodes or double-balanced mixers with switch-type FETs has eased the large-signal handling problem of just a decade ago.

One weak link in the chain, however, remains; this is the synthesizer, with its inherent noise contributions. To a large extent the overall architecture of the receiver and the synthesizer determines its performance, and even the best high-performance components — placed in the wrong sequence — can cause a good design to fail.

systems approach

Because military and commercial users depend on high performance receivers for surveillance and/or point-to-point communication, it's inevitable that these same technological advances will filter down to the Amateur community. In fact, in a cursory examination, the spec sheets of both commercial and Amateur communications receivers look quite similar.

Besides providing the "essentials," modern communication receivers offer additional features, sometimes referred to as "bells and whistles"; these features include improved user interfaces or computer interfaces for remote control. Since the commercial and Amateur markets are price-sensitive and also very sensitive to proof of performance, any claims of lower capabilities are noticed. Consequently, when on-the-air tests of some late-model receivers suggested poorer performance than previous models, this raised the question of why, despite the knowledge acquired in recent years, such an inconsistency should occur.

Figure 1 is a functional block diagram of a modern microprocessor-controlled communication receiver. This diagram is representative of most modern design approaches and can be used to evaluate possible advantages and weaknesses, and to point out areas of potential difficulty.

operation

The rf signal is introduced into the receiver in one of two ways:

- at the input of a 30-MHz low-pass filter via a variable attenuator, which is controlled by an overload detection circuit activated at the first and second i-f level;
- or for receiving frequencies below 400 kHz, via a variable attenuator and low-pass filter combination.

The first mixer, which is responsible for the third-order intercept point, is driven by an extremely pure synthesized local oscillator. To terminate the double-balanced mixer properly, a diplexer (high-pass/low-pass filter) is used to absorb energy outside the crystal filter passband. The input impedance of the crystal filter rises significantly outside the passband of the crystal filter.

By Ulrich L. Rohde, KA2WEU/DJ2LR, 52 Hillcrest Drive, Upper Saddle River, New Jersey 07458

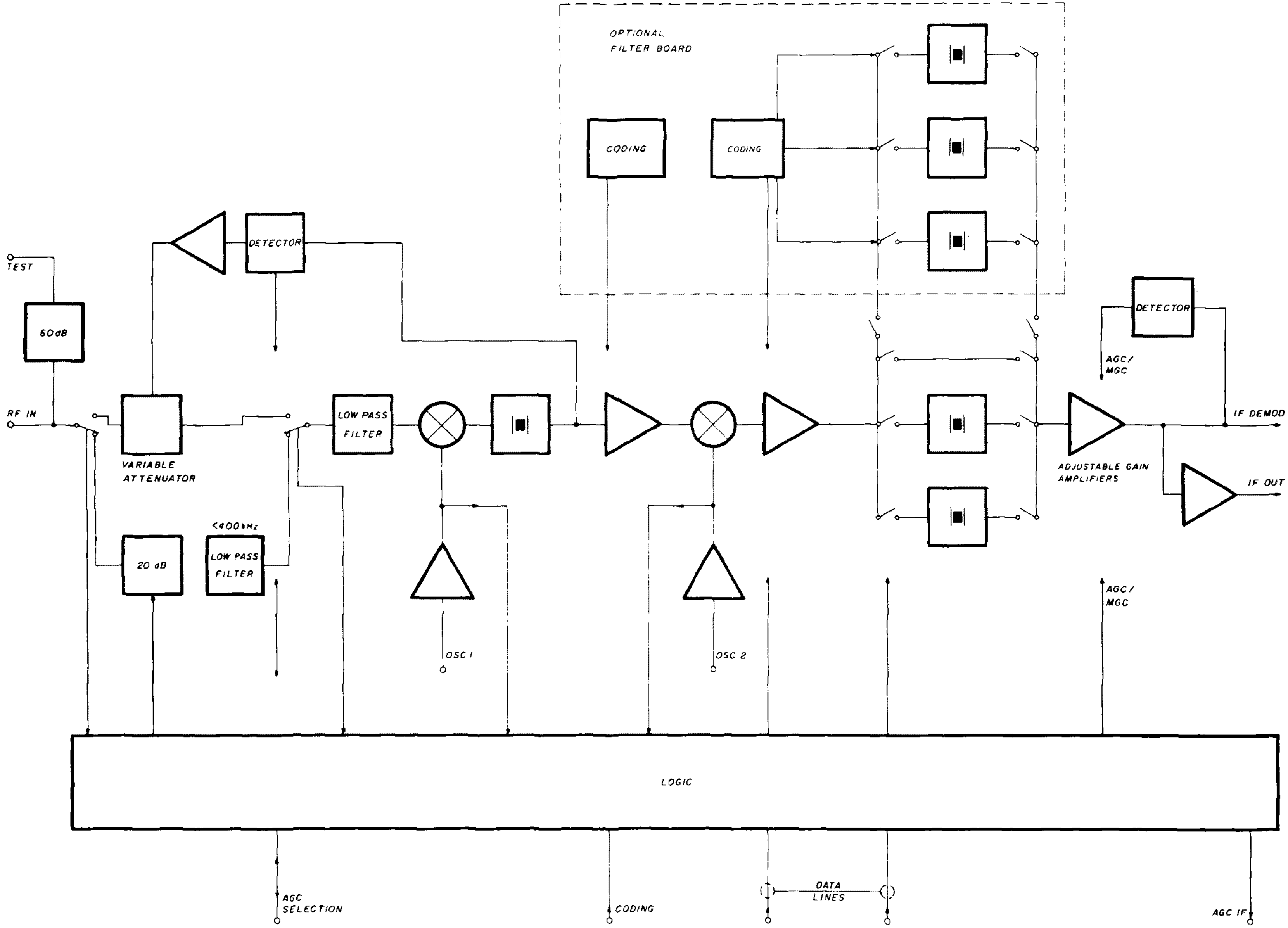


fig. 1. Functional block diagram of a modern microprocessor-controlled communication receiver.

While most commercial or military high-performance receivers employ the input stage combination, most Amateur equipment uses a double-balanced mixer that incorporates adjustable-gain JFETs. As a result of its sensitivity to output impedance changes, the mixer suffers reduction in large- signal performance. The recent trend in mixer design involves the use of termination-insensitive mixers whose cleverly designed bridge circuits ignore the effects of reactive terminations. Passive mixers use hot carrier diodes; switching-type mixers use FETS — for example, a pair of matched SD 100 transistors — and achieve intercept points between +35 and +45 dBm.

Following a six- to eight-pole crystal filter is an amplifier stage which has medium gain and high dynamic range. This is typically achieved through the use of rf feedback. In addition, it is worthwhile to incorporate an AGC circuit between this amplifier and the mixer.

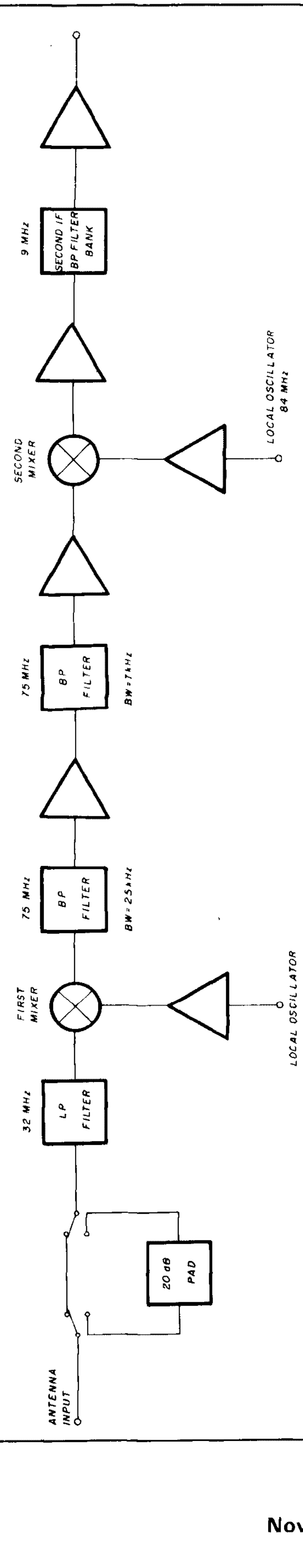
The signal, which is now in the 75- to 100-MHz frequency range, is converted to a low i-f frequency — for example, from 200 kHz to 2 MHz — by the second mixer. The second mixer must also have high dynamic range, but it can be a passive double-balanced mixer. (The latest advances in receiver design have included the use of careful filtering of the local oscillator synthesizer outputs, thereby reducing spurious responses.) The amplifier that follows this mixer compensates for the second i-f mixer losses. This, in turn, is followed by a popular frequency range crystal filter that is readily available from a number of manufacturers.

gain distribution is important

Each of these stages has very little gain — typically less than 12 dB. The main amplification of the signal takes place in the i-f sections. (This is different from what happens in Amateur receiver designs.) The problem with designing most of the gain into the i-f stages has to do with the ability to build the i-f amplifier circuits stable and free of unwanted oscillations. To minimize in-band intermodulation distortion, differential-type amplifiers with AGC stages are used. In many cases this requires a great deal of shielding and careful selection of grounds, since up to 100-dB open loop gain in the i-f section may be required.

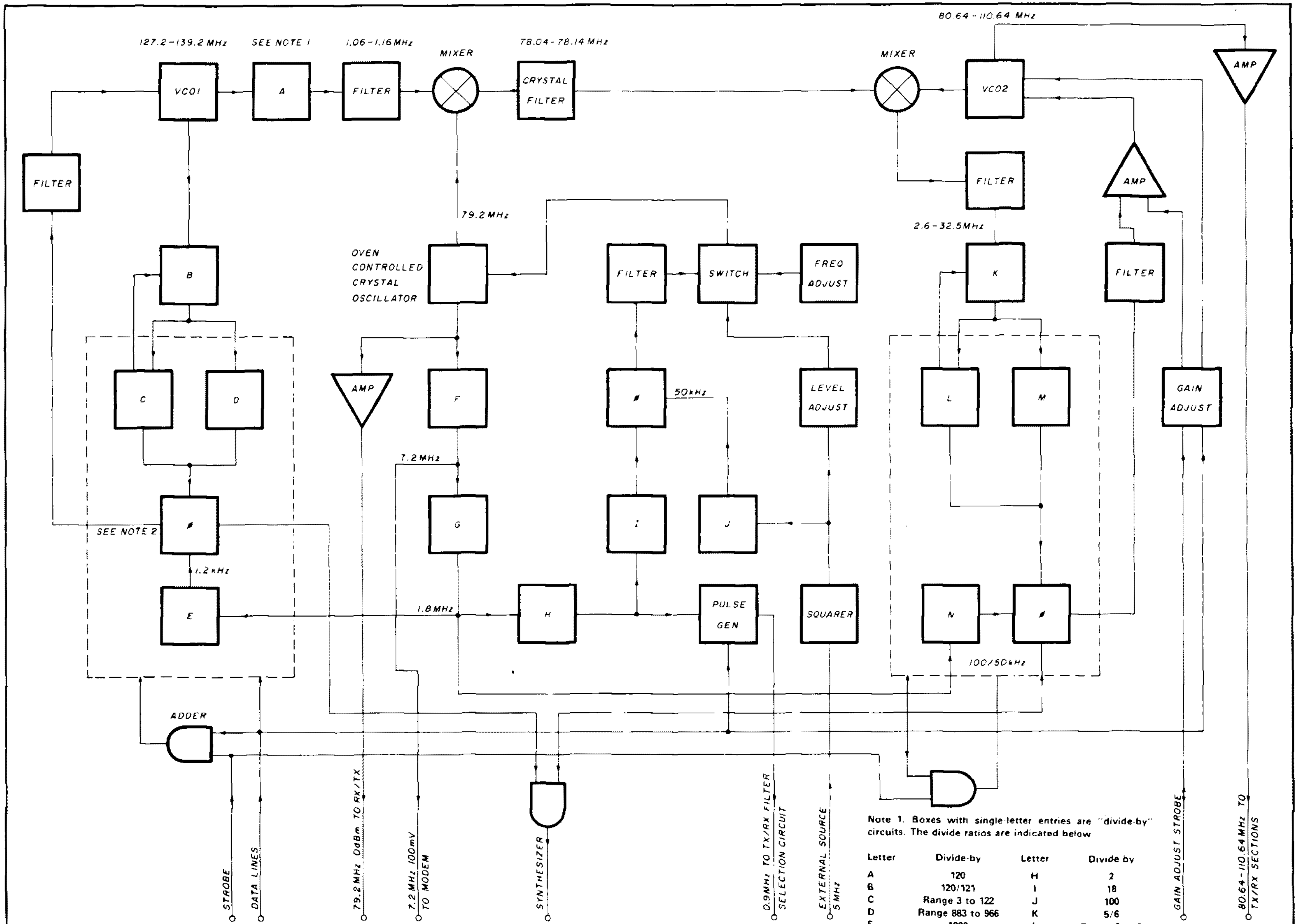
One sign of good receiver design is evident when the noise of the first mixer, with no antenna connected, already shows slight AGC action, which can be monitored on the S-meter of the receiver. If signals of 1-μV or better are required before any S-meter action occurs, then the above design guidelines have *not* been followed.

Although I've noted these things thoroughly and repeatedly in previous articles, very few companies have followed through with this concept because it's much less expensive to move the gain towards the antenna than to build high-gain i-f stages.



Power gain	dB	-0.5	6	1	10	3.5	12	6	8	4	>90
Noise figure	dB	–	6	–	2	–	3	6	5	–	4
Cumulative noise figure	dB	10.81	10.31	4.31	3.31	8.18	4.68	12.02	6.02	8	4
IP_2	dBm	–	80		·	–	·	·	·	–	*(out)
Cumulative IP_2	dBm	86.5	86	–	–	–		–	–	·	*(in)
IP_3	dBm	–	32	–	30	–	30	27	30	–	*(out)
7 kHz in-band IP_3	dBm	13.9	13.4	7.4	6.4	16.6	13.1	26.8	22	–	*(in)
25 kHz in-band IP_3	dBm	27.2	26.7	21	20	–	·	·	·	–	*(in)
Out of band IP_3	dBm	38.5	38		·		·	·		–	[illegible]

fig. 2. Noise, gain, and intermod products are indicated on this block diagram of a modern communications receiver.



Note 1. Boxes with single-letter entries are "divide-by" circuits. The divide ratios are indicated below

Letter	Divide-by	Letter	Divide by
A	120	H	2
B	120/121	I	18
C	Range 3 to 122	J	100
D	Range 883 to 966	K	5/6
E	1200	L	Range 3 to 5
F	11	M	Range 9 to 64
G	4	N	18 or 36

fig. 3. Multi-loop frequency synthesizer utilizes carefully separated analog and digital circuits.

Note 2. All boxes labeled with Greek letter "phi" are phase detectors.

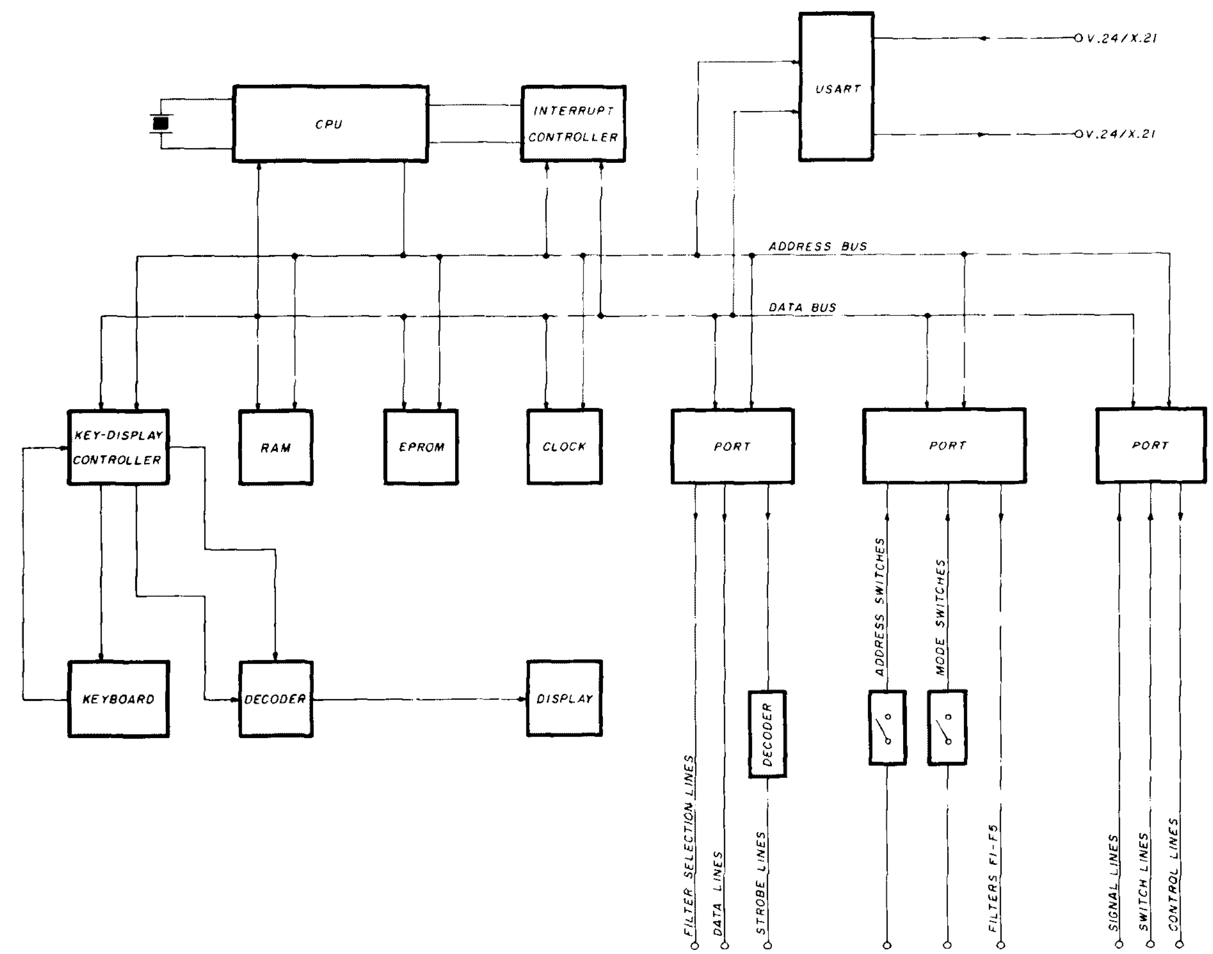


fig. 4. Architecture of the internal computer system found in a modern fully synthesized receiver.

Interestingly enough, the NRD 525 receiver, which follows these recommendations but is still fairly inexpensive, is one of the better designs. **Figure 2** shows a typical block diagram with the various noise, gain and intermodulation distortion products specified. Such an analysis must be carried out and should be published together with the receiver specifications.

In **fig. 1**, the internal bus for the receiver that controls a variety of functions transfers digital data streams that consist of short-duration pulses with fast rise times. Consequently, significant shielding is required in this section in order to isolate the digital circuits and their concommitant switching spikes from the analog portion of the receiver. Many modern receivers suffer from this effect, in which background switching noise masks lower level signals. To make things worse, the synthesizer can also pick up some of the switching signals.

synthesizer design

Modern receivers should incorporate fully synthesized local oscillators and provide between 1- and 10-Hz resolution. All of the auxiliary frequencies in the design must be derived from the master (oscillator) standard.

The frequency synthesizer in this example uses two main loops in its multi-loop design. VCO1, which oscillates between 127 MHz and 139 MHz, is phase locked in steps of 1.2 kHz; its output is then divided by 120 to an output frequency of approximately 1 MHz, which is then mixed with the 79.2-MHz standard. The difference frequency components are introduced into a 78.1-MHz crystal filter which removes all unwanted signals. The other portions of the synthesizer provide auxiliary frequencies. The areas where the phase detectors are located are heavily shielded; fairly high frequencies for the reference detectors are used for best noise performance.

Figure 3 shows a synthesizer that utilizes this design approach. In this design, analog and digital circuits are carefully separated. The sections of the synthesizer most vulnerable to picking up extraneous signals are the lines going into the output VCO (VCO2).

Depending on the type of phase detector used, the lines that feed the tuning diodes can be either very high impedance or low impedance. Inexpensive solutions frequently lead to such high-impedance feeding points, which then become "antennas" collecting all the switching noise. The use of circuits incorporating microwave transistors allows the design of discrete low-impedance amplifiers for this purpose. If the driving point impedances for the tuning diodes can be held at 100 ohms as opposed to the 100-k line impedance typically found, the sensitivity for pickup of stray signals is reduced by a factor of 100,000.

Another reason for noisy synthesizers is the use, in the synthesizer loops, of operational amplifiers that are too noisy. Wherever possible, either discrete low-noise amplifiers or Darlington stages must be used.

use of microprocessors

Today's microprocessor-controlled receivers feature built-in clocks, frequency scanning with variable scan rates, availability of at least 100 channels and channel scanning, plus a combination of receiver control functions such as the serial RS-232 or IEEE-488 bus remote control capabilities. Because the BFO and the main oscillator are both synthesized, the combination of the two allows either passband tuning or variable bandwidth.

Another area of interest in the use of microprocessors is the linearization of the transfer characteristic of the tuning range of the oscillator and the linearization of the S-meter. The microprocessor can also switch the tuning rates to correspond to the operating mode and select the appropriate bandwidth receiving crystal filters required for that same mode. Digital implementation of signal analysis allows demodulation of RTTY and Morse code. Many other novel approaches are possible.

Figure 4 shows the architecture of such an internal computer system. One of the frequent mistakes made in this context is the use of only one microprocessor, which gets overloaded, or the use of four-bit microprocessors. In better radios, eight-bit microprocessors, which can handle all these functions efficiently, are used. The best approach is parallel processing.

summary

By following these simple guidelines and using architecture similar to that illustrated in **figs. 1** and **2**, it is possible to build receivers that come close to the limits of physics, yet still remain cost- effective.

bibliography

Ulrich L. Rohde, KA2WEU/DJ2LR, *Digital PLL Frequency Synthesizers. Theory and Design*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632, 1983 (Currently out of print, this book is available in limited quantities through the author.)

Ulrich L. Rohde, *T. T. N Bucher Communications Receivers. Principles and designs*, McGraw Hill, New York, N. Y., 1988.

ham radio

a CAT control system
for the Yaesu FT-757GX

C-64 BASIC routine tunes popular transceiver

An earlier article on the CAT system, based on the Tandy TRS-80 Model 100, attracted the attention of a considerable number of users of Commodore 64® microcomputers.[1,2] But while it was a relatively simple task to convert the TRS-80 program for other micros with a standard RS-232C port, it wasn't as easy to convert the program for the popular C-64.

Converting the unique Commodore "inverted TTL level" format is no problem because the CAT system also works with TTL levels. But the standard baud rates of the C-64 stop at 2400, and CAT works at 4800 baud. (In this case, baud and bps give the same number, so we'll stick to "baud," since that's what's used in the Commodore and Yaesu literature.)

It's possible to obtain the proper parameters for 4800 baud using a two-step formula for calculating "user-specified baud rates."[2] Checking the output with an oscilloscope looked promising, but in practice the data transfer wasn't reliable, and bytes sometimes were lost on their way from BASIC to the radio. Commodore specialists have several explanations for this. Some say that it depends on the physical layout of the printed circuit board; others contend that Commodore BASIC has problems handling the NUL character. Whatever the reason, the data didn't always reach the RS-232C output buffer in good order.

In this program these problems are avoided by replacing the BASIC RS-232C statements with routines written in machine language. The parameters are POKEd into temporary storage in memory locations 52592 to 52596. The command byte (see **table 1**) goes into location 52592. The frequency number is sliced into four bytes (i.e., 12,345.67 kHz converts to 01, 23, 45 and 67), which are stored in the next four locations.

Another problem has also been solved in machine language. The frequency bytes just mentioned are in the CAT Binary Coded Decimal format, and ideally would be passed as such to the RS-232C port. But the Commodore BASIC interpreter expects all numbers to be in decimal form and converts them into hexadecimal when the program is executed. A look-up table is used to reconvert the hex into the proper BCD format. The five bytes are then sent out one by one, starting from the highest address, as required by the CAT system.

BASIC program

The BASIC part of the program (**fig. 1**) is straightforward and can be segmented as follows:

The program is initialized in **lines 100** to **220**. A title screen at **lines 3000** to **3160** (subroutine) is displayed while the machine language part in **lines 4000** to **4114** (subroutine) is being loaded. **SYS 52480** is similar to **OPEN File No. 1** for 4800 baud, eight bits per byte, two stop bits, and no parity. **Line 210** determines the starting frequency.

The main screen is set up in **lines 1000** to **1150** (see **fig. 2**). The keys available for commands are indicated within brackets. The upper row on the keyboard is used for general commands; the lower row — plus "A" and ";" — for tuning in steps of 10 Hz to 100 kHz. "F" is for steps of any size and "Q" for quitting the program.

Note that Band Down and Band Up have different functions, depending on whether the FT-757GX is in Amateur Band or General Coverage mode, and whether or not MR/VFO has been activated (see the FT-757GX Operating Manual). This short program doesn't take into account frequency changes made with Band Down or Band Up, so in order to get the correct screen display, you'll need to reinitialize the program by pressing "F" and entering the actual frequency before using the Fine Tuning keys. This isn't a problem, since you can still go directly to any frequency with the "F" command.

By **Kjell W. Strom, SM6CPI**, P.O. Box 2, I-28041 Arona, Italy

Table 1. *Command byte codes.*

function	hexadecimal	decimal
Band Down (multifunction)	08	8
Band Up (multifunction)	07	7
Dial Lock (on/off)	04	4
Clarifier (on/off)	09	9
Split Frequency (on/off)	01	1
Switch between VFO A and B	05	5
Transfer VFO to Memory	03	3
Transfer Memory to VFO	06	6
Exchange between VFO and Memory	0B	11
Temporary check of Memory	02	2
Frequency Set	0A	11

fig. 1. BASIC language program for CAT control of Yaesu FT-757GX.

```
10 REM =============================
20 REM CAT CONTROL FOR YAESU FT-757GX
30 REM        AND COMMODORE 64
40 REM   BY KJELL W. STROM, SM6CPI
50 REM                 JUNE 5, 1987
60 REM =============================
70 REM
100 REM *** LOAD ML AND OPEN FILE FOR 4800 BAUD ***
110 GOSUB 3000:GOSUB 4000:SYS 52480
200 REM *** SET INITIAL FREQ (10000 KHZ) ***
210 A=10000
220 GOSUB 2100
1000 REM *** MAIN SCREEN ***
1010 PRINTCHR$(147)"[RVS]  YAESU FT-757GX CAT PROGRAM BY SM6CPI  "
1015 PRINT:PRINT:PRINT
1020 PRINT"NEW FREQUENCY [F]                 QUIT [Q]"
1030 PRINT:PRINT:PRINT:PRINT"                 FINE TUNING"
1040 PRINT"             << - <KHZ> +> > "
1050 PRINT"[A]100                              100[;]"
1060 PRINT
1070 PRINT"10   5   1  .1  .01 .01 .1   1   5   10"
1080 PRINT"[Z] [X] [C] [V] [B] [N] [M] [,] [.] [/]"
1090 PRINT"[DOWN]----------------------------------"
1100 PRINT"    [1] BAND DOWN      [2] BAND UP"
1110 PRINT"    [3] DIAL LOCK      [4] CLARIFIER"
1120 PRINT"    [5] SPLIT FQ       [6] VFO A/B"
1130 PRINT"    [7] V=>M           [8] M=>V"
1140 PRINT"    [9] V=>/<=M        [0] MR/VFO"
1150 PRINT "[HOME][DOWN][DOWN]           KHZ":PRINT"[UP]"A
1160 GET C$:IF C$="" GOTO 1160
1170 IF C$="B" THEN A=A-.01:GOTO 1600
1180 IF C$="N" THEN A=A+.01:GOTO 1600
1190 IF C$="V" THEN A=A-.1:GOTO 1600
1200 IF C$="M" THEN A=A+.1:GOTO 1600
1210 IF C$="C" THEN A=A-1:GOTO 1600
1220 IF C$="," THEN A=A+1:GOTO 1600
1230 IF C$="X" THEN A=A-5:GOTO 1600
1240 IF C$="." THEN A=A+5:GOTO 1600
1250 IF C$="Z" THEN A=A-10:GOTO 1600
1260 IF C$="/" THEN A=A+10:GOTO 1600
1270 IF C$="A" THEN A=A-100:GOTO 1600
1280 IF C$=";" THEN A=A+100:GOTO 1600
1290 IF C$="F" THEN GOSUB 2800:GOTO 1000
1300 IF C$="1" THEN POKE 52592,8:SYS 52526:GOTO 1160
1310 IF C$="2" THEN POKE 52592,7:SYS 52526:GOTO 1160
1320 IF C$="3" THEN POKE 52592,4:SYS 52526:GOTO 1160
1330 IF C$="4" THEN POKE 52592,9:SYS 52526:GOTO 1160
1340 IF C$="5" THEN POKE 52592,1:SYS 52526:GOTO 1160
1350 IF C$="6" THEN POKE 52592,5:SYS 52526:GOTO 1160
1360 IF C$="7" THEN POKE 52592,3:SYS 52526:GOTO 1160
1370 IF C$="8" THEN POKE 52592,6:SYS 52526:GOTO 1160
1380 IF C$="9" THEN POKE 52592,11:SYS 52526:GOTO 1160
1390 IF C$="0" THEN POKE 52592,2:SYS 52526:GOTO 1160
1580 IF C$="Q" GOTO 2900
1590 GOTO 1160
1600 REM *** ROUND OFF AND CHECK RANGE ***
1610 A=INT(A*100+.5)*.01
1620 IF A<500 THEN A=500
1630 IF A>29999.99 THEN A=29999.99
1640 GOSUB 2100
1650 GOTO 1150
2100 REM *** SLICE FREQ AND OUTPUT ***
2110 A$=MID$(STR$(A),2)
2120 IF A=INT(A) THEN A$=A$+"."
2130 A$="000"+A$+"00"
2140 FOR I=1 TO LEN(A$)
2150 DP$=MID$(A$,I,1)
2160 IF DP$="." THEN DP=I:GOTO 2400
2170 NEXT
2400 A$=MID$(A$,DP-6,6)+MID$(A$,DP+1,2)
2410 F1=VAL(MID$(A$,1,2))
2420 F2=VAL(MID$(A$,3,2))
2430 F3=VAL(MID$(A$,5,2))
2440 F4=VAL(MID$(A$,7,2))
2450 POKE 52593,F1
2460 POKE 52594,F2
2470 POKE 52595,F3
2480 POKE 52596,F4
2490 POKE 52592,10
2500 SYS 52512
2510 RETURN
2800 REM *** NEW FREQUENCY ***
2810 INPUT"[DOWN][DOWN][DOWN]FREQUENCY KHZ";A
2820 A=INT(A*100+.5)*.01
2830 IF A<500 THEN A=500
2840 IF A>29999.99 THEN A=29999.99
2850 GOSUB 2100
2860 RETURN
2900 REM *** REM CLOSE FILE AND QUIT ***
2905 PRINT:PRINT:PRINT
2910 PRINT"                          ARE YOU SURE?"
2920 GET C$:IF C$="" GOTO 2920
2930 IF C$="Y" THEN SYS 52578:PRINT CHR$(147):END
2940 GOTO 1000
3000 REM *** TITLE SCREEN WHILE ML IS LOADING ***
3010 H1$="      C A T  P R O G R A M  F O R"
3020 H2$="      Y A E S U  F T - 7 5 7 G X"
3030 H3$="          BY KJELL W. STROM, SM6CPI"
3040 PRINTCHR$(147):PRINT:PRINT:PRINT:PRINT
3050 FOR I=1 TO LEN(H1$)
3060 PRINT MID$(H1$,I,1);
3070 NEXT
3080 PRINT:PRINT
3090 FOR I=1 TO LEN(H2$)
3100 PRINT MID$(H2$,I,1);
3110 NEXT
3120 PRINT:PRINT:PRINT
3130 FOR I=1 TO LEN(H3$)
3140 PRINT MID$(H3$,I,1);
3150 NEXT
3160 RETURN
4000 REM *** LOAD ML ROUTINES ***
4010 FOR I=52480 TO 52696:READX:POKEI,X:NEXT
4020 RETURN
4100 DATA 169,1,162,2,160,3,32,186,255,169,4,162,104,160,205
4101 DATA 32,189,255,32,192,255,162,3,189,108,205,149,247,202
4102 DATA 16,248,96,162,3,188,113,205,185,117,205,157,113,205
4103 DATA 202,16,244,162,1,32,201,255,173,14,220,41,254,141
4104 DATA 14,220,162,4,189,112,205,168,173,161,2,41,1,208,249
4105 DATA 152,32,210,255,202,16,238,173,161,2,41,1,208,249
4106 DATA 32,204,255,173,14,220,9,1,141,14,220,96,169,1,32
4107 DATA 195,255,96,0,0,2,0,0,206,0,207,75,87,83,56,55,0,1,2
4108 DATA 3,4,5,6,7,8,9,16,17,18,19,20,21,22,23,24,25,32,33
4109 DATA 34,35,36,37,38,39,40,41,48,49,50,51,52,53,54,55,56
4110 DATA 57,64,65,66,67,68,69,70,71,72,73,80,81,82,83,84,85
4111 DATA 86,87,88,89,96,97,98,99,100,101,102,103,104,105,112
4112 DATA 113,114,115,116,117,118,119,120,121,128,129,130,131
4113 DATA 132,133,134,135,136,137,144,145,146,147,148,149,150
4114 DATA 151,152,153
10000 REM *** 'RUN 10000' FIRST TO CHECK ML DATA LINES ***
10010 S=0:FORI=52480TO52696:READX:S=S+X:NEXT
10020 IF S<>22360 THEN PRINT"CHECK ML DATA!":END
10030 PRINT"ML DATA OK!"

READY.
```

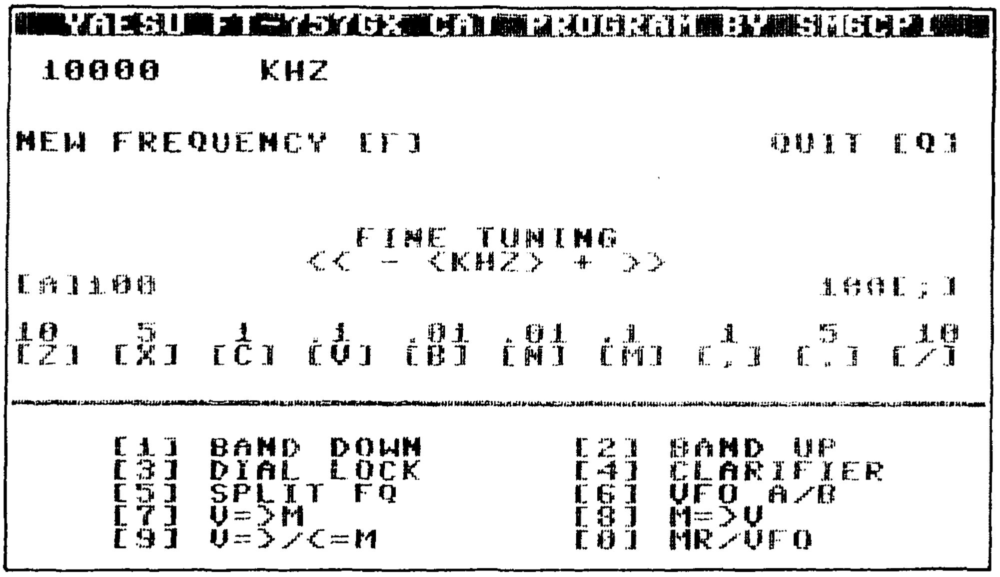


fig. 2. Screen display.

Commands entered from the keyboard are decoded by **lines 1160** to **1590. SYS 52526** sends the bytes to the radio without converting from hex to BCD, since this isn't required for the single-byte commands.

Verification that the frequency is inside the range of the FT-757GX is accomplished with **lines 1600** to **1650.**

In **lines 2100** to **2510** the frequency parameter is sliced into four bytes, as described above, after having been converted into a string and having found the position of the decimal point. **SYS 52512** is the call for sending out the frequency byte after a hex-to-BCD conversion.

The frequency input subroutine used with the "F" command is contained in **lines 2800** to **2860.**

The subroutine for the QUIT command is in **lines 2900** to **2940.**

The last part of the program contains subroutines for the title screen and for loading of the machine language part, as mentioned before.

The numbering of the program lines may seem haphazard; this is because some numbers were intentionally omitted in order to reduce the time needed for some of the GOSUBs and GOTOs. Renumbering to a tighter sequence may slow down the program a little.

After typing in the program, SAVE it and type **RUN 10000 / RETURN** / to confirm that the DATA lines have been entered correctly. Otherwise, if there's a mistake in the DATA and you try a RUN, you may lose the program!

interface

An interface circuit serves two purposes: it translates the input level to a suitable output level and stops potentially harmful interference from one connected unit from reaching the other, and vice versa.

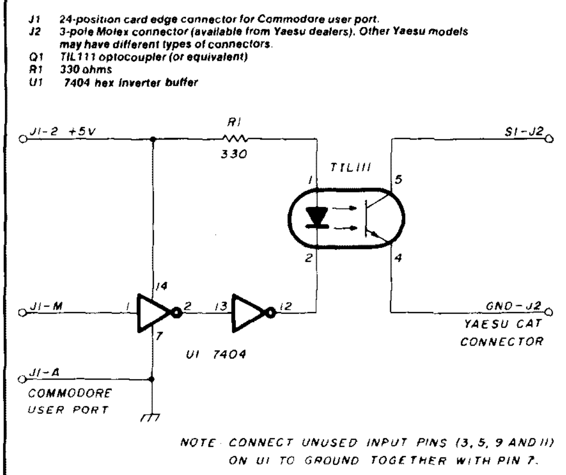


fig. 3. Schematic diagram.

Both the C-64 and the FT-757GX CAT system work with the same TTL levels, but the current needed to pull the CAT SI line to low, through a 680-ohm resistor, is probably higher than can be considered safe for the delicate C-64 CIA chip. We also want to minimize the possibility of computer noise reaching the receiver and of transmitter rf reaching the computer.

The Yaesu FIF-232C interface does this job. It accepts the inverted TTL level format from the C-64 if the internal switch S01 is set to the position opposite from nor-

mal. Since it also works with standard RS-232C format and with the two-way CAT systems of the FT-980, FT-757GX II, and FT-767GX, it can be regarded as a very flexible solution, especially since it has its own built-in power supply.

For our purpose we can also use the simple interface circuit shown in **fig. 3**. It receives 5 volts from the C-64 and can be assembled on a small IC-spacing perforated board as close as possible to the 24-position user port card edge connector. The cable from the TIL111 optocoupler output side should be shielded, with the screen connected to ground at the transceiver side only, not to computer ground. Connect all unused input pins on the 7404 IC to ground, together with pin 7.

summary

This article has been intended to show how easily you can interface and use the CAT system with the Commodore 64 and the Commodore 128 in C-64 mode. It also offers four machine language routines you can use in much more powerful programs, thereby adding your own special features to one of today's most appreciated transceivers.

references

1. K. W. Strom, SM6CPI, "A CAT Control System," *QST*, October, 1985, page 38.
2. K. W. Strom, SM6CPI, "Feedback", *QST*, April, 1986, page 41.

ham radio

the weekender

a thumbwheel frequency selector for the Yaesu FT-757GX

If you happen to own a Yaesu FT-757GX transceiver, this one-evening project will make its operation more convenient and enjoyable. If you don't own one, you may find that this article will show the ease and simplicity with which features of modern computer-controllable radios can be accessed.

Because the 757's minimum incremental tuning is in 500-kHz steps and the tuning dial moves only 10 kHz per rotation, any frequency change in other than 500-kHz steps takes several presses of the button and an average of 12-1/2 knob rotations! This project allows thumbwheel entry of any frequency, in or out of the current band. The design makes *no* modifications to the radio and connects to it with only two plugs on the back panel. A circuit board layout is given for those who wish to etch a board; the design can also be wire-wrapped, with no degradation in performance. All normal radio functions — including tuning with normal front panel controls — are still available.

design considerations

It's best to think of the thumbwheel frequency selector (TWFS) as a unidirectional data source. Yaesu provided an interface to accept commands from an external source on the back panel of the 757, which, among other things, accepts serially encoded binary data as requests for frequency selection options; these are documented on page 10 of the 757 Technical Supplement Manual. In addition to duplicating front panel

Brian J. Mork, KA9SNF, 215 Paddock Drive East, Savoy, Illinois 61874

operations, a command is provided for loading any specific frequency. Using this command, discrete frequencies may be entered without all the front panel dial spinning. The 757 never sends data, so no provision needs to be made for data flow *from* the transceiver.

This circuit sends a prepackaged stream of 50 bits to the radio at 4800 bits per second every time you push a "load" button. The outputs of six BCD thumbwheel switches are part of the 50-bit stream and indicate what frequency is requested. The thumbwheels provide frequency selection with a resolution of 100 Hz. A two-wire data cable goes from the TWFS to the radio back panel and connects to pins 1 and 2 (the left and middle pins as viewed from the back) of a three-pin connector formally designated as J12 or the EXT CNTL jack. (See pages 9, 10, and 40 of the 757 Technical Supplement Manual for additional details.)

This pair of data wires, carrying TTL voltage levels, is the only connection to the 757 radio that's necessary. But in order to operate the TWFS, a power source providing 5 volts is also required. One additional connection to the 757 back panel provides 13.8 vdc at 800 mA through an RCA phono plug. Using a three-terminal fixed regulator to convert the 13.8 volts provided by the transceiver to a regulated 5 volts, the prototypes were measured to draw 165 mA from the radio. If no other accessories use this connection, it may be used to power the TWFS.

design details

The schematic for the TWFS is shown in **fig. 1**. The 555 provides the clock pulses to the 74LS393 at a frequency of 19.2 kHz. The internal Q_a and Q_b stages of the 393 divide the signal frequency by 4 and the remaining six count-stages provide a 6-bit binary number updated at the rate of 4800 Hz. The frequency adjustment of the 555 is done with a ten-turn rheostat. Frequency stability of the 555 is sufficient in this application because of the short bursts of data that are sent. For instance, assume that the Yaesu can tolerate a 1/8 bit error in order to read the data correctly. A 1/8 bit error on the 50th bit implies 0.25-percent relative error, allowing a frequency range of the 555 from 19.152 to 19.248 kHz.

The 393 is configured as a 6-bit counter that automatically shuts itself off when it gets to a count of 50. Every time the load button is pressed, the counter is reset to zero and counts to 50 one more time. The 6-bit binary number generated by the 393 is interpreted by the three 74150 and one 153 multiplexers so that one of 50 TTL levels are sequentially provided at the output of the 153.

When no data is being sent (i.e., you haven't pressed the load button recently), both address lines to the 153 are high and the HALT signal on pin 13 of

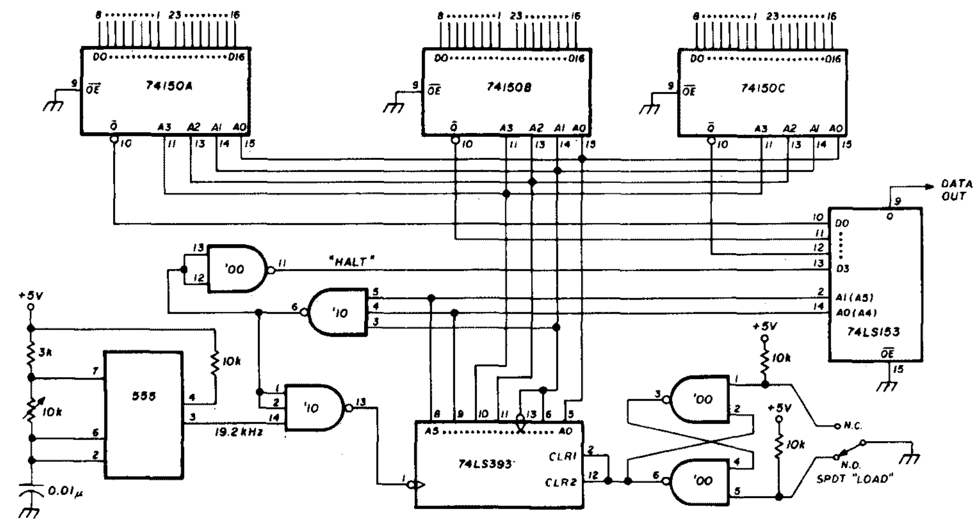


fig. 1. Schematic for the TWFS. Connections for these 48 pins are given in tables 2 and 3.

Table 1. Wiring and data description.

Bit no.	Data source	Wire to	Description	Bit no.	Data source	Wire to	Description
0	74150A – 8	0	partial bit				
1	– 7	1	start	26	74150B – 21	p20	1 MHz – 1
2	– 6	1	10 Hz – 1	27	– 20	p19	1 MHz – 2
3	– 5	1	10 Hz – 2	28	– 19	p22	1 MHz – 4
4	– 4	1	10 HZ – 4	29	– 18	p21	1 MHz – 8
5	– 3	1	10 Hz – 8	30	– 17	0	stop
6	– 2	p4	100 Hz – 1	31	– 16	1	start
7	– 1	p3	100 Hz – 2	32	74150C – 8	p24	10 MHz – 1
8	– 23	p6	100 Hz – 4	33	– 7	p23	10 MHz – 2
9	– 22	p5	100 Hz – 8	34	– 6	p26	10 MHz – 4
10	– 21	0	stop	35	– 5	p25	10 MHz – 8
11	– 20	1	start	36	– 4	1	100 MHz – 1
12	– 19	p8	1 kHz – 1	37	– 3	1	100 MHz – 2
13	– 18	p7	1 kHz – 2	38	– 2	1	100 MHz – 4
14	– 17	p10	1 kHz – 4	39	– 1	1	100 MHz – 8
15	– 16	p9	1 kHz – 8	40	– 23	0	stop
16	74150B – 8	p12	10 kHz – 1	41	– 22	1	start
17	– 7	p11	10 kHz – 2	42	– 21	1	
18	– 6	p14	10 kHz – 4	43	– 20	0	
19	– 5	p13	10 kHz – 8	44	– 19	1	
20	– 4	0	stop	45	– 18	0	
21	– 3	1	start	46	– 17	1	
22	– 2	p16	100 kHz – 1	47	– 16	1	
23	– 1	p15	100 kHz – 2	48	– HALT –	command	
24	– 23	p18	100 kHz – 4	49	– HALT –	to load	
25	– 22	p17	100 kHz – 8	50	– HALT –	frequency	

NOTE: The column headed "Wire to" lists either a header pin number, a "0," or a "1." Header pin numbers 1 and 2 are grounded. Each of the remaining 24 header pins must have a 10k pullup resistor. "0" bits are wired to ground and "1" bits are wired to the 580 – ohm pullup resistor. The column headed "Description" indicates how the bit will be interpreted by the 757 transceiver. Remember that the 150s invert the data.

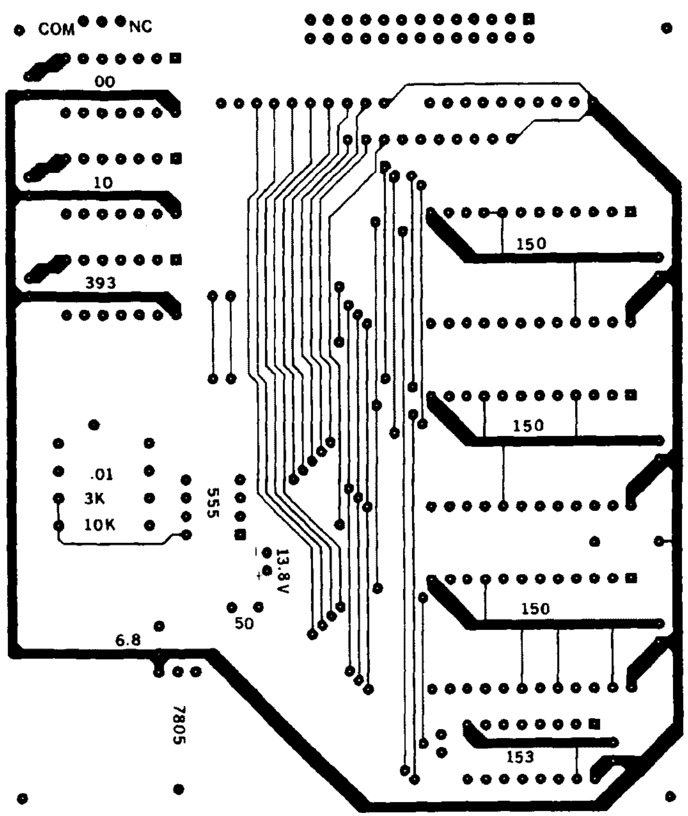


fig. 2. Upper (component) side artwork of frequency selector circuit. Be sure to use IC sockets that allow soldering on the top side of the board.

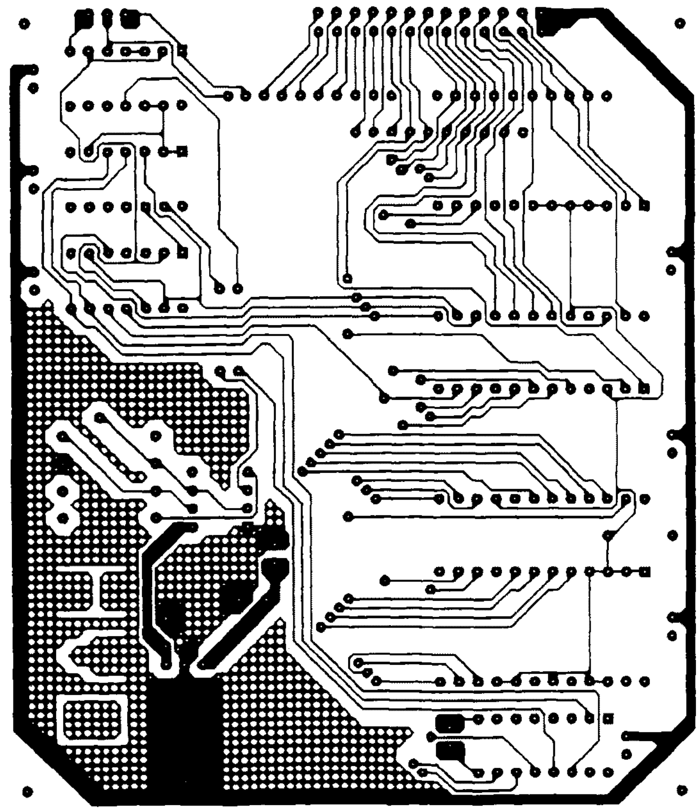


fig. 3. Lower (major foil) side artwork of frequency selector circuit.

Components for thumbwheel frequency selector.

Integrated circuits	
1	*7805*
1	*555*
1	*74LS00*
1	*74LS10*
1	*74LS393*
1	*74LS153*
3	*74150*
Resistors (all 1/4 watt)	
1	*580-ohm (pullup for 17 TTL lines)*
26	*10k (thumbwheel and two switch pullups, 3x9 SIPS)*
1	*10k miniature ten-turn potentiometer*
1	*3k (555 timing)*
1	*10k (555 timing)*
Capacitors	
7	*0.01μF (IC decoupling)*
1	*0.01μF (555 timing, mylar)*
1	*50μF (decoupling of 13.8-volt supply, electrolytic)*
1	*6.8μF (decoupling of 5-volt supply, tantalum)*
Hardware	
1	*7805 heatsink*
1	*Pushbutton switch, 1-pole, 2-throw*
6	*BCD thumbwheel switches*
1	*RCA phono plug (power, 757 connector)*
1	*3-pin SIP socket (0.1-inch spacing, 757 connector)*
1	*26-pin, 0.1-inch DIP header and socket*
1	*3-pin 0.1-inch SIP header and socket*
2	*2-pin 0.1-inch SIP header and socket*
1	*Cabinet*

the 153 is available as data — a TTL high level. As soon as you press the load button, the 393 counter clears to zero and pin 8 of 74150A is sent out as data. Because your button presses aren't synchronized with the clock, this first bit of data may or may not be held for a full 208.3 μsec (1/4800). That's OK because it's a TTL high signal — the same as the quiescent voltage level. In effect, the bit sequence has started but the 757 doesn't care that the first bit is too short because it doesn't recognize the TTL high level as the first bit.

The next 40 bits (bits 1-40) encode the thumbwheel-selected frequency digits. Data is sent in four 8-bit chunks. Each chunk is prefixed with a start bit (TTL low) and followed by a stop bit (TTL high), yielding a total of 40 bits. Within each 8 bits, two BCD numbers are sent least significant bit first. These numbers are read directly from the contacts of the thumbwheels, necessitating selection of thumbwheel switches with BCD outputs. The frequency is sent least significant digit first. The 100-MHz digit and the 10-Hz digit are permanently wired as zero. The 10-MHz through 100-Hz digits are read from the thumbwheels.

The last 8-bit value sent is decimal 10, which indicates to the transceiver that all the previous data should be interpreted as a frequency. The start bit and the first 6 bits of this data are retrieved through the 150/153 multiplex chain as all other bits were. The last 3 bits (0,0,1, sent in that order) actually reflect the status of the counter HALT signal. During the last 3 bits (48-50) the HALT line, which goes high to disable the counter when a count of 50 is reached, is fed through the 153. During counts 48 and 49, it is false (TTL low); on the 50th count, it goes true (TTL high). Because 555 pulses are locked out with this same signal, the data line stays indefinitely high.

Note that the 150 chip inverts data before passing it to the 153. This is the way most BCD switches work — grounding the logical true pins. Bits 0-47 are sent through the 150s and so are wired inverted. Bits 48-50 (the HALT line) are not inverted by the 153 alone.

construction

The artwork for a double-sided circuit board is shown in **figs. 2** and **3**. A parts list is provided. The entire prototype was built using available components, though substitutions may be made. The only critical parts values are in the 555 timer circuit, and even these values could be recalculated to allow use of what you have in stock, following the formulas provided in manufacturers' data books. Although low-power Schottky integrated circuits are called for wherever possible, standard TTL chips would suffice. The power supply drain will increase, but no difference in operation will be noticed.

The circuit is simple enough to be wire-wrapped by hand; in fact, the prototype was wired on two small prototype boards with all the little holes. Provision is made on the pc board for a 7805 voltage regulator and its two bypass capacitors, assuming the 13.8 volt supply from the radio will be used. This portion of the circuit is not shown on the schematic. Refer to a manufacturer's data book or the ARRL's *Radio Handbook* for details about the 7800 family of regulators. The connections to the 48 data lines of the 150s are listed in **table 1**.

Power connections and unused pins for all ICs are tabulated in **table 2**. I advise the following general order of construction and check-out. Using IC sockets, wire the entire circuit, including all non-IC components. Component placement — following the markings on the circuit board — should be straightforward. Each of the IC positions is marked with a square pad to indicate pin 1. Three columns of ten holes provide a mount for the SIP resistor packages. If SIPs aren't available, mount nine 10k resistors on end, then connect all the tops of the resistors together and into the tenth hole (5 volts). Three holes are provided for a horizontal-style ten-turn potentiometer. Two holes relatively close together provide a mount for a radial lead, 13.8-volt decoupling capacitor, but a larger axial lead capacitor can be mounted by doubling one lead back next to its casing.

Four off-board connections need to be made. The power and data connections are each made with two wire cables. The load switch connects to the board

Table 2. Power connections and unconnected pins for ICs.

IC	+5 volts	Ground	Not Connected
555	8	1	5
74LS393	14	7	3,4
74LS10	14	7	8-11
74LS00	14	7	8-10
74LS153	16	8	1,3-7
74150	24	12	None

Table 3. Bit sequences for two sample frequencies: (A) 10.000 MHz, and (B) 29.999 MHz. The data sent by the TWFS will be interpreted by a normal ASCII computer terminal as the characters listed. Ten^H bit groups must be sent with a maximum of 100 msec betwwen them in order to be interpreted correctly by the transceiver.

(A) 10.000 MHz

bits 1-10:	0 0000 0000 1	cntrl-@
11-20:	0 0000 0000 1	cntrl-@
21-30:	0 0000 0000 1	cntrl-@
31-40:	0 1000 0000 1	cntrl-A
41-50:	0 0101 0000 1	line feed

(B) 29.999 MHz

bits 1-10:	0 0000 1001 1	cntrl-P (8 bit set)
11-20:	0 1001 1001 1	cntrl-Y (8 bit set)
21-30:	0 1001 1001 1	cntrl-Y (8 bit set)
31-40:	0 0100 0000 1	cntrl-B
41-50:	0 0101 0000 1	line feed

with three wires. Each of these connections can use 0.1-inch space header strips for neatness. The connection to the thumbwheels is made with a 26-pin 0.1-inch space dip header. Twenty-five pins are needed (24 BCD data lines and one common ground line); they're listed in **table 1**.

Install the 7805 regulator. A mounting hole is provided for laying the regulator flat on its back, but it can be left upright if you wish. In either case, a heatsink is suggested. Apply power and verify that the correct voltages are applied to the proper IC socket pins. With the power off, insert only the 555. Then — with the power back on — check to see that pin 14 of the 74LS10 socket is receiving an oscillating TTL signal. Adjust the ten-turn potentiometer until a frequency of 19.20 kHz is obtained. Turn the power off.

Install the 393, the 10, and the 74LS00. Apply power again and confirm that pins 2 and 12 of the 393 are stable at a TTL low level. Pressing and holding the load switch should make these pins go to a high level. As you're holding in the switch, pin 1 of the 393 should be receiving an oscillating signal. Release the load switch. Pin 1 should stop oscillating in approximately 10.4 msec (the time needed to send 50 bits). If a digital event counter is available, measure pin 5 of the 393. It should be low while the load button is depressed and count 25 low-to-high transitions when the load button is released. Many frequency counters can be used as event counters by locking their count gate open.

With the power off, install the remaining four ICs. Turn on the power one last time, using the plug on the back of the radio if that's your final intention. At this point, the data output (pin 9 of the 153) should be stable in a TTL high state and a valid 5-byte sequence of data should appear whenever the load switch is pressed and released. Connect the ground side of the data connection to the left side and the data line itself to the center pin of the three-pin connector on the back of the 757 (J12). Dial a valid Amateur band frequency on the thumbwheels and press the load button. The radio should switch directly to that frequency!

If the transceiver doesn't switch to the requested frequency after you release the load button, most likely one of the data lines into the 150 multiplexers has been wired incorrectly. If, after careful checking, everything looks correct, the following procedure may reveal the problem. Disconnect pin 3 of the 555 from its IC socket (bend it out horizontally) and plug a slowly oscillating TTL signal (about 4 Hz) or a low-pulse generator into pin 3 of the socket. Press and release the load switch. A TTL high level should be available as output data. Every four oscillations of the signal generator should cause pin 5 of the 393 to change and the data line to the radio should update. Set the frequency to 100000 and confirm the bit sequence shown in **table 3(A)**. A frequency of 299999 should provide the bit sequence shown in **table 3(B)**.

conclusion

This should be a fairly simple project for anyone who has worked — even just a little — with digital logic circuits. The idea of simply multiplexing hard-wired data sequentially out a data line is about as simple a communication scheme as possible. I hope others will expand this concept to enable a computer to provide data to the radio. I know useful commercial programs are available, but designs that add greatly to operating convenience don't need to be difficult to do yourself!

Ironically, although I've had fun designing the circuit and building several copies of it, I no longer have a 757 with which to use it. Therefore, I wish to express thanks to Gary LaPook, KA9UHH, for the use of his radio during the design of the project and for proofing the first prototype under actual use conditions. *There's a hamfest coming up. I wonder what a used 757 might cost?*

ham radio

ham radio TECHNIQUES

Bill Orr, W6SAI

a new country for you?

We were sitting on the beach in front of the luxury hotel. As cool tradewinds caressed us, we enjoyed a second tall, iced glass of Long Island Iced Tea (1/3 each vodka, gin, and white rum, with a splash of cola for color).

"How about going on a DXpedition to a new country?" I asked The Big DXer.

"No way," he replied. "Look at the cost of the Bear Island trip. Activating a new country is too expensive these days."

I gestured toward the horizon. "There's your new country — only a few miles away. You can spend your nights right here in this dandy resort, living it up, and helicopter over and back each day. A 15-minute trip to a new country! Think how many hams you'd make *very* happy!"

The Big DXer stared at the island. "It looks easy," he said. "What's the trick? Why hasn't it been activated before?"

"Well," I replied, "there's a little problem . . . ."

The barren island of Kahoolawe lies a scant dozen miles south of the island of Maui, Hawaii. Uninhabited, it has no water or electric power. Jurisdiction rests with the United States Navy, much as in the case of Midway Island; the same reasons that Midway is accepted as a separate DX country, then, should be applicable to Kahoolawe.

The "little problem" is that this island is known as the "bombing island" because it's used by the military for bombing and assault practice. The whole surface of the island, it is said, is covered with unexploded ordinance. There's a boat dock, however, with an area around it that's considered safe for occupancy. Armed with a gasoline generator, a transceiver, and a portable antenna, DXers could conceivably operate from this area — *if* they could obtain permission to land.

Squinting at the island, The Big DXer admitted, "It would be nice to know who in the Navy to approach. Maybe a DXpedition to Kahoolawe is in the cards after all. I'll have another Long Island Iced Tea."

the 10, 18, and 24-MHz bands

As a result of an ITU conference some years ago, Radio Amateurs were granted operating privileges in narrow bands in the 10, 18 and 24-MHz region. Let's look at these bands as they appear in the fall of 1987, together with some simple antennas that will get you on these bands quickly.

Although the 50 kHz-wide *10-MHz band (10.100 to 10.150 MHz)* has enjoyed a modest amount of CW activity over the years, it's still largely ignored by most Amateurs. One or two loud commercial stations operating in this range must be avoided, but otherwise the band is good for DX — if activity can be found.

It seems to me that in order to awaken general interest in the band, a portion of it should be opened to sideband operation. I therefore propose that the top 25 kHz be opened to sideband. Before the band became available for general Amateur use, I operated sideband on 10.105 MHz with an experimental license for several months; I can attest to the fact that allocating even a small segment of this assignment to sideband would be of great benefit to Amateur Radio. How about a petition in this regard, ARRL?

Although available to Amateurs in over 40 countries, the *18-MHz band (18.068 to 18.168 MHz)* is barred to United States hams because of alleged use by the military. But a number of operators monitored this frequency region for several months during the early summer of 1987 — see **fig. 1** for a summary of the results of their work.

There's a small amount of overseas Amateur CW operation from 18.068 to 18.075 MHz. Sometimes there's a RTTY signal on 18.070. When it's ac-

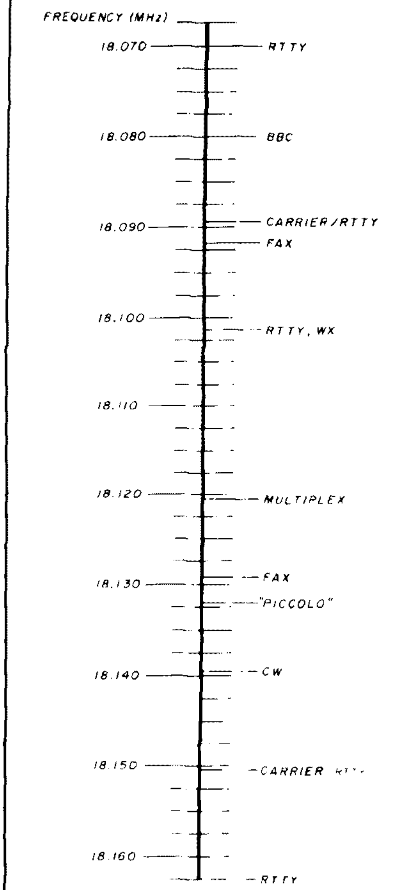


fig. 1. Spread of non-Amateur signals in the 18.068- to 18.168-MHz range.

tive, that frequency is avoided. This signal isn't on often, however, and when it's on, it's usually in "idle" mode. The BBC overseas service is quite active on 18.08, and there's a cluster of RTTY and FAX activity from 18.088 to 18.093 MHz.

Two RTTY weather signals are quite active near 18.104, with a multiplex signal slightly higher than 18.120 MHz. Near 18.130 there's a FAX transmission with a "piccolo" signal just above it. There are CW signals near 18.140 and 18.150. At the top of the range, there are several RTTY stations near 18.165 MHz.

It isn't clear that any or all of these stations are United States military. *In* fact, some of the signals sound as if they're arriving from overseas. None of them are on continuously except for the BBC relay transmission on 18.080 MHz, which is very active.

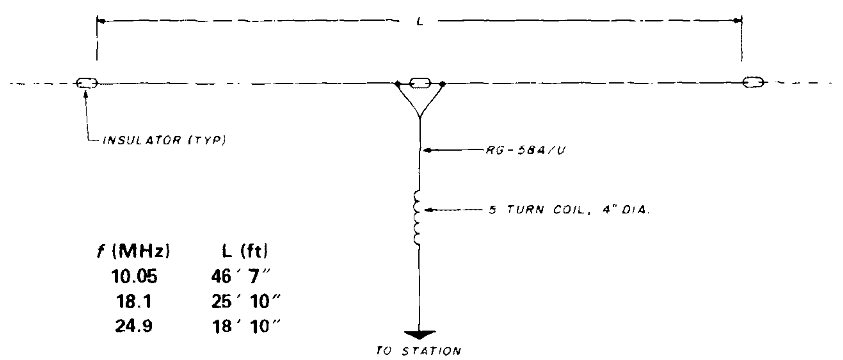
Amateur sideband operation takes place around 18.10 MHz. Stations in Europe, Africa, South America, and Australia have been logged from time to time.

After observing the 18-MHz band for over four years, it seems to me that the military's need for this span of frequencies makes for a pretty thin argument. I propose that the burden of proof of usage be placed on those opposing the presence of United States Amateurs in this band. Merely stating that the band is in use by the military, without proof of occupancy, should not justify the FCC's withholding the band until 1989.

Australia had several government and military assignments in this frequency range. When they opened the band to VK hams, they merely identified certain small spots as "off limits" to Amateur operation. Our government could do the same thing if it wanted to!

The 24-MHz band (24.89 to 24.99 MHz) is in good use and, as the sunspot cycle rises, will quickly become one of the better DX bands. Overseas DX signals pound in, even from stations running low power. Make sure you operate this band during the fall and winter DX season!

You can get on the 10, 18, and 24-MHz bands quickly with a dipole antenna cut to the dimensions shown in **fig. 2**. Even if you can't transmit on these bands, I urge you to listen, just to get the "feel" of propagation in these interesting portions of the radio spectrum.



f (MHz)	L (ft)
10.05	46′ 7″
18.1	25′ 10″
24.9	18′ 10″

fig. 2. A "quickie" dipole for 10, 18, or 24 MHz. Feedline is wound into choke at point it attaches to antenna. Waterproof coax end at antenna.

W0SVM's mini-dipole

Amateurs have used miniature antennas on 40 meters for years. The smallest antenna that comes to mind is the loaded 40-meter mobile whip. Some hams who've placed two of them back-to-back to form a compact dipole (about 16 feet long) have found that the mini-antenna works quite well if it's mounted up in the air.

Even so, the 16-foot antenna is still too big for some hams who are unlucky enough to be handicapped by location. How about an indoor 40-meter antenna?

Jack Sobel wrestled with this idea for some time and finally came up with the antenna shown in **fig. 3**. He decided to use a long, thin radiating coil, or helix. Many hams frown on the helix antenna, but Jack and others have had good luck with the configuration.

Since material was at hand to make an antenna about 2 feet long, he decided this length would be a good place to start. The idea was to wind the antenna into a helix, or coil, and then place a matching coil at the center. Because the radiation resistance of the helix was bound to be

very low, Jack chose a tapped matching coil technique to approximate a match to a 50-ohm line. And since antenna *Q* would be very high, he decided to use a Transmatch at the station end of the transmission line.

construction details

The antenna can be wound on a cardboard mailing tube. Coils L1 and L2 are 10 inches long and wound at six turns per inch (60 turns per coil of No. 12 AWG insulated wire). Coil L3 is 5 inches long and wound at six turns per inch (30 turns) of No. 12 tinned wire. Coil L3 is wound in the direction *opposite* to the direction in which coils L1 and L2 are wound. The braid of the coax line is attached to the center point of L3, and the center conductor is tapped out until a match is found to provide the lowest value of SWR at the resonant frequency of the antenna. Resonance is established with the aid of a dip meter before the antenna is attached. The tap point is about 2/3 the distance from the center to one end of L3. (The exact point depends upon the coupling between the antenna and nearby objects and the exact spacing of the windings.)

The antenna is fed with an electrical half-wavelength of RG-58/U coax. The line can be coiled up if it's too long to fit the available space.

The passband of the antenna is quite sharp, and if operation across the 40-meter band is desired, a Transmatch is necessary at the transmitter end of the line.

The antenna should be sprayed with a transparent polyurethane material or "corona dope" (a cellulosic resin such as General Cement's No. 10-4702). So far, the antenna has been run only at low power levels; since there may be danger of corona discharge at the outer ends of the windings, it's best to use the spray coating to help prevent this.

The antenna should be mounted as high in the air as possible and placed in a position where it can't be touched. There's *very* high rf potential at the ends of the little antenna, and an unsuspecting person could get a nasty rf burn during transmitter operation.

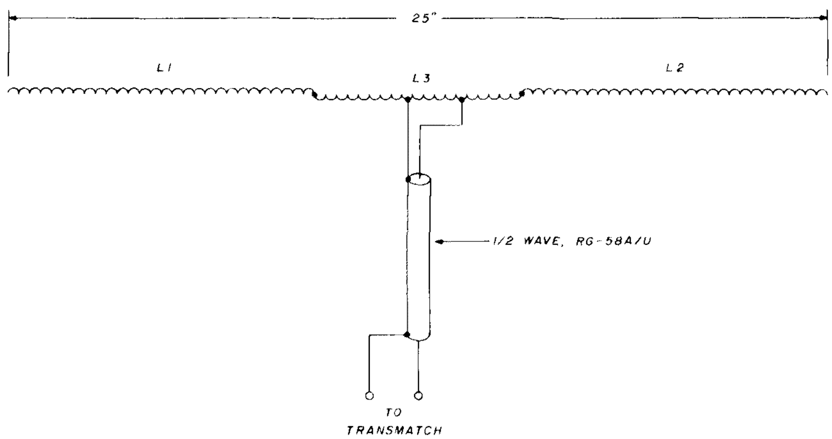


fig. 3. The mini-antenna of W0SVM. Adjust coax tap for best SWR at resonance.

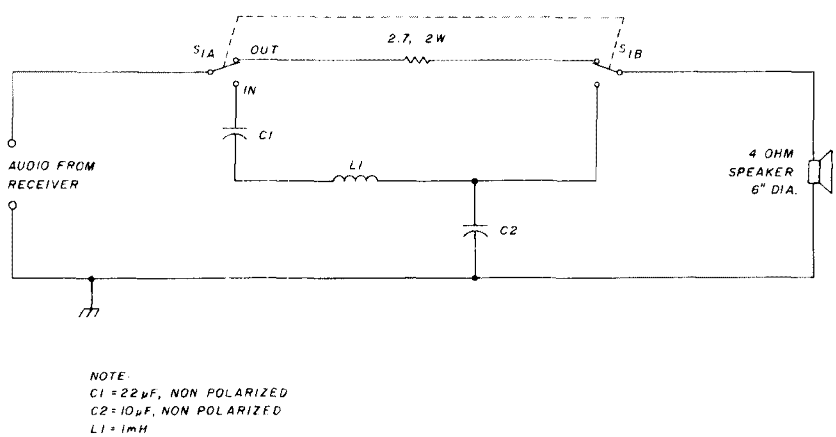


fig. 4. Communications network speaker system.

If more space is available, two mailing tubes can be epoxied together and the turns-per-inch increased so that the antenna covers more length along the longer tube. The winding will have to be readjusted to frequency with a dip meter if this change is made.

So far, Jack's contacts have been limited to a few hundred miles on 40 meters. He says it isn't as good as a full-size dipole, but it's small and can be used in an apartment.

a communications speaker system

Tired of listening to that annoying high-frequency "monkey chatter" that seems to sneak through the receiver filter system? It can be extremely tiring, especially in a DX contest. The VK boys seem to have a handle on that problem. Rodney Champness, VK3UG, writing in the March, 1987, issue of *Amateur Radio*, the publication of the Wireless Institute of Australia, shows a simple audio filter that can be placed in the speaker line (**fig. 4**) to substantially reduce frequencies above 2500 Hz. A switch on the filter allows normal wideband reception to be retained.

The 1-mH inductor should be able to carry the audio current in the speaker circuit (something less than 1 ampere).

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

using voltage comparators

A voltage comparator is basically an operational amplifier (or derived from the op amp) that has no negative feedback network (see **fig. 1A**). The open-loop gain of the op amp is very high — on the order of 50,000 at the low end to more than 1,000,000 for many devices. Thus, with no negative feedback the operational amplifier functions as a very high-gain amplifier with an output that saturates with only a few millivolts input potential. For example, with a gain of 100,000, and a maximum output potential of 10 volts, the amplifier will saturate with only 10 volts/100,000, or 0.1-mV input.

So what use is an amplifier that saturates with only a few millivolts of input voltage? The comparator is used to compare two input voltages and generate an output that denotes their relationship. In **fig. 1A**, potential V_1 is applied to the inverting input, and V_2 is applied to the noninverting input. If $V_1 = V_2$, then $V_o = 0$. Otherwise, the output voltage obeys the relationships shown in **fig. 1B**. The transfer function of the comparator is shown in **fig. 1B**. According to the normal rules for operational amplifiers, when V_1 is larger than V_2 (see **fig. 1A**), it looks as if a positive input has been applied to the inverting input, so the output potential saturates at V−. Alternatively, when V_1 is smaller than V_2, it looks like a negative input potential, so the output is V+.

Typical Amateur examples include over- and under-deviation alarms on repeater receiver detector outputs, and over-temperature alarms for electronic equipment. For example, some form of alarm is needed at unattended repeater sites. The comparator can be used to let the control operator know by telephone or radio telemetry link that something is amiss. Other applications will occur to most readers in the light of their own special needs.

There is a small hysteresis band around zero, however, where no output changes occur. This is an unfortunate defect in practical op amps, and seems to fly in the face of the theory when that hysteresis band is larger than the potential needed to saturate the output terminal.

Several years ago, while working in a hospital electronics lab, I measured the hysteresis band on a number of operational amplifiers and IC comparators (LM-311). Not surprisingly, the 741-family devices had terrible hysteresis levels, on the order of 25 mV. The LM-311 devices had 8- to 10-mV hysteresis, which surprised me. Also surprising was the fact that then-premium devices such as the μA-725 had 10 to 20 mV of hysteresis (I haven't tested modern high-performance units). The overall best device was a non-premium device that is readily available to Amateurs and other hobbyists: the CA-3140 (a BiMOS operational amplifier), which uses the industry standard "741" pinouts, as shown in **fig. 1A**.

The LM-311 device (**fig. 2A**) is a low-cost voltage comparator in IC form. Although based on op amp cir-

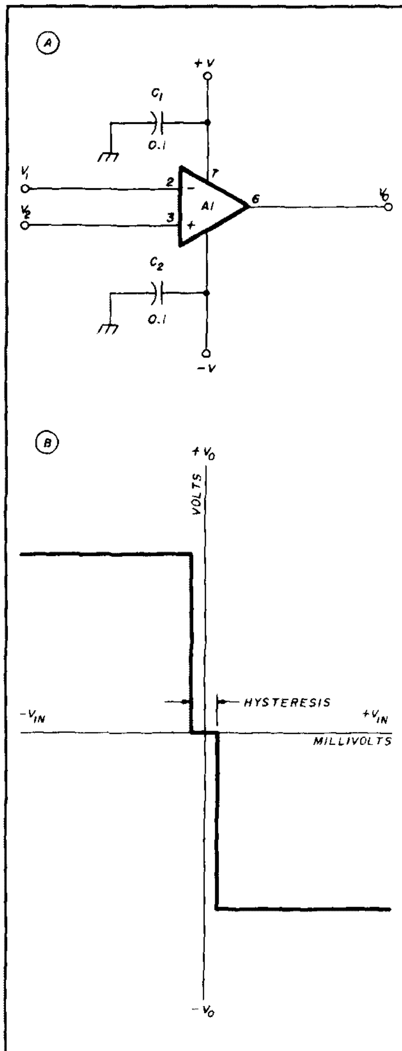


fig. 1. (A) Simplified diagram of voltage comparator; (B) comparator transfer characteristic.

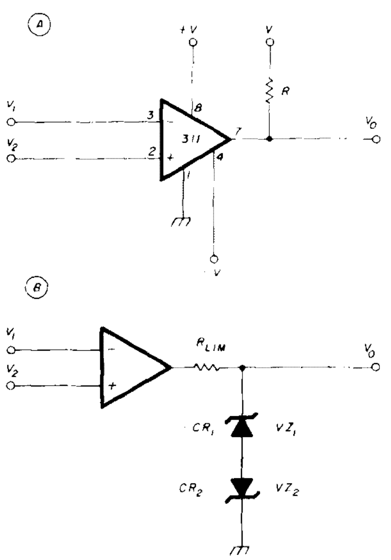


fig. 2A. LM-311 voltage comparator.

fig. 2B. Zeners improve transfer characteristic and speed, and limit output voltage of the comparator.

cuitry, this device is specifically designed as a comparator. Contrary to op amp practice, it has a ground terminal (pin 1) and requires an output pull-up resistor (R) to a positive voltage. The output terminal can drive loads such as relay coils, lamps, and LEDs to potentials of 40 to 50 volts (depending upon the type of device) and 50 mA. If the LM-311 is operated for compatibility with TTL digital logic, the pull-up resistor should be terminated at a +5 VDC potential, and R should be 1 to 3.3 k.

A means for limiting the output level, improving the sharpness of the transfer function corners (see **fig. 1B**), and improving speed by reducing latch-up problems, is shown in **fig. 2B**. In this circuit, two zener diodes are connected back-to-back across the output line. When the output voltage is HIGH, it is then limited to V_{Z1} + 0.7 volts; when LOW, it is V_{Z2} + 0.7 volts. These potentials represent the zener voltages of CR_1 and CR_2, plus the normal forward-bias voltage drop of the alternate diode.

Figure 3 shows a means for increasing the drive capacity of the comparator. In this circuit a switching transistor (a 2N3704, 2N2222, etc.) is used to control a larger load such as the relay coil shown here. The output voltage (V_0 of the comparator) is used to set up the bias for the NPN transistor. When the comparator output is HIGH, the transistor is biased hard-on and the load is grounded. Alternatively, when the comparator output is LOW, the transistor is reverse biased and the load remains ungrounded.

The diode across the relay coil is essential for any inductive load. When the magnetic field surrounding a coil collapses the counter EMF generates a high-voltage spike that is capable of damaging components or interrupting circuit operation (especially digital circuits). Though the diode is normally

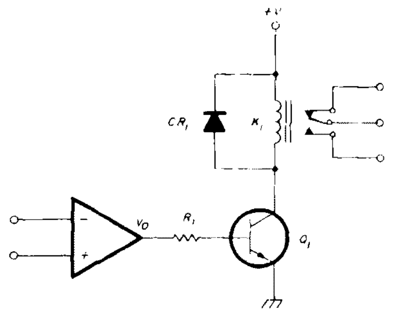


fig. 3. Addition of switching transistor allows higher current loads to be controlled.

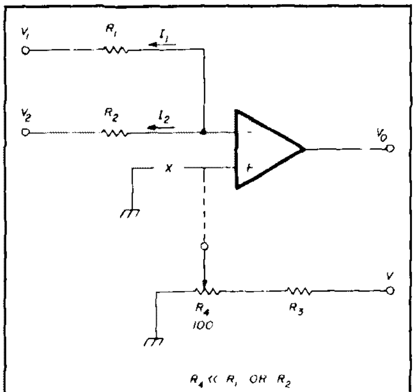


fig. 4. Two methods of reducing the hysteresis band effect: zero offset control and current mode operation.

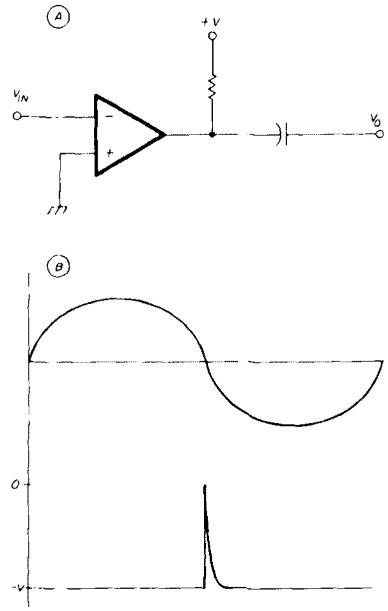


fig. 5. Zero crossing detector circuit and waveforms.

reverse biased, it is forward biased for the counter EMF spike. The diode therefore clamps the spike to about 0.7 volts.

Figure 4 shows two methods. One is a zero-offset control used to reduce the effects of the hysteresis band, while the other is the so-called current mode. The offset control (R_4) slightly biases one input to a non-zero level so that it's ready to trip when the other input is non-zero. In this particular case the inverting input is grounded (V_2 = 0), but could as easily be a non-zero voltage.

Current mode operation is usually faster and less prone to latch-up than voltage mode. For this reason, current mode comparators are sometimes used in high-speed analog-to-digital converters (A/D). Assume that the noninverting input is grounded. In this case, the output potential V_o will reflect the relationship of the two currents. If $I_1 = I_2$, then $V_o = 0$. This circuit is, to the outside observer, a voltage comparator in that $I_1 = V_1/R_1$ and $I_2 = V_2/R_2$. Of course, it's also useful for current output devices such as the LM-334 temperature monitor IC.

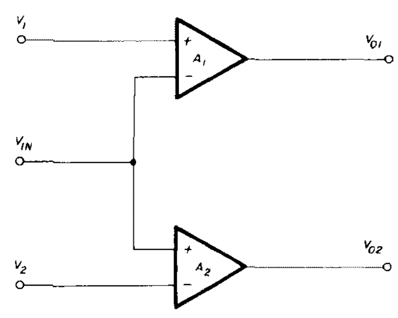


fig. 6. Window comparator triggers on two different reference levels being exceeded.

Figure 5 shows a zero-crossing detector circuit. In this case a comparator is connected with its noninverting input grounded. When V_{in} is non-zero, then the output will also be non-zero. But when the input voltage crosses zero, the output briefly goes to zero, producing the differential output pulse shown.

A window comparator is shown in **fig. 6**. This circuit consists of two comparators connected so that one or the other input is activated when the input voltage (V_{in}) exceeds either positive or negative limits. The limits are determined by setting V_1 or V_2 reference voltages. An over- and under-deviation alarm, as heard on some repeaters, is a possible application for this circuit. The output of the fm demodulator is a voltage that is proportional to deviation, so this circuit is a natural for that use (although the demodulator voltage will probably require some amplification). The circuit is also used for over- and under-temperature alarms, and other such applications where a range of permissible values exists between two forbidden regions.

Figure 7A shows a method for biasing either input to a specific reference voltage. Although in this case the noninverting input is biased and the inverting input is active, the roles can just as easily be reversed. Two methods of biasing are used: resistor voltage divider and zener diode. If R_2 is replaced with a zener diode, then the reference potential is the zener potential. In that case, R_1 is the normal current-limiting resistor needed to protect the zener from self-destruction. In the case where a resistor voltage divider is used, the bias voltage V_1 is set by the voltage divider equation:

$$V_1 = \frac{R_2\,(V+)}{R_1 + R_2} \tag{1}$$

For example, suppose $R_1 = R_2 = 10k$, and $V+ = 12$ VDC:

$$V_1 = \frac{(10k)\,(+12\ VDC)}{(10k + 10k)}$$

$$V_1 = \frac{120\ volts}{20k} = 6\ volts$$

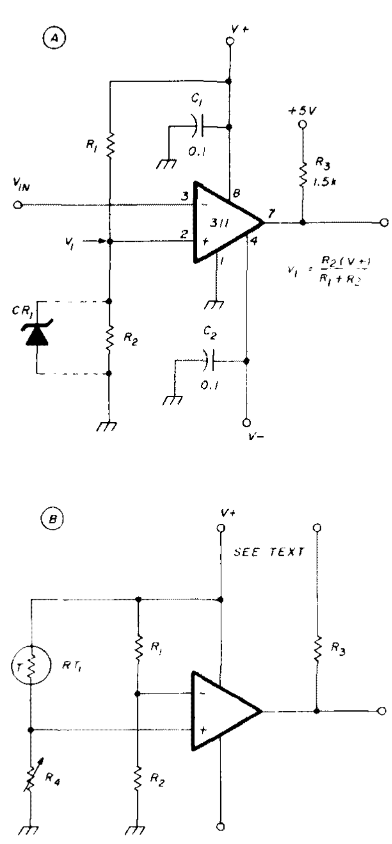


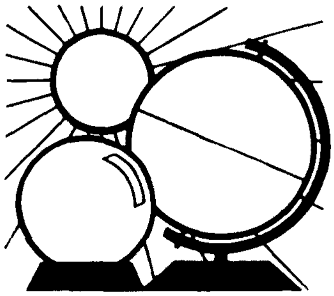
fig. 7. (A) Method of biasing comparator to a specific reference voltage; (B) over-temperature sensing circuit is biased by R_1/R_2 resistor combination.

Figure 7B shows an over-temperature circuit based on **fig. 7A**. In this circuit the inverting input is biased by R_1/R_2, while the noninverting input is set by another voltage divider, R_4/RT_1. Resistance RT_1 is a thermistor, which has a resistance proportional (or inversely proportional in some types) to the temperature. Potentiometer R_4 is used to set the trip point temperature. The values of the resistors depend upon the set trip point desired and the resistance of the thermistor over the range of temperatures being monitored.

an invitation

I'd like to hear what you think of this column. I also welcome your suggestions for future topics. You can reach me at P.O. Box 1099, Falls Church, Virginia 22041.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

winter DX

With the fall DX season (September and October) behind us, the winter DX season (November through February) is about to begin. Wintertime DX is characterized by:

- Better signal strengths on all bands most of the time — but especially during daytime on the lower frequencies, particularly in low sunspot years.
- Nighttime DX openings earlier in the evening.
- More frequent transequatorial paths, with higher MUFs and longer distances.
- Lower incidence of local thunderstorm-generated QRN conditions.
- More stable signal strengths and fewer geomagnetic field disturbances.

There are two main reasons for the first four characteristics: the tilting of the Earth's axis away from the sun, which results in shorter, colder days; and less ionization in the lower ionosphere, which results in less energy absorption as signals travel through the D region.

The amount of absorption per hop is related to the zenith angle to the sun at the location of each D region crossing. In working DX, it pays to use a higher frequency band to obtain more distance per hop (resulting in fewer transits) for less total signal loss. This is why we generally think of 6, 10, or 15 meters for DXing.

But in winter, particularly near sunspot minimum, we have the opportunity to work DX on the lower frequency bands with lower signal loss, day or night, than at any other time of the year. You can't always count on it, however; signals traveling a high latitude path may be poor for several days at a time. This is known as the *winter anomaly*.

Along with lower signal attenuation, QRN decreases as fewer local thunderstorms pass through. As the large thunderstorm areas near the equator move further south, their noise decreases by about 6 to 8 dB. This is particularly noticeable on the 160, 80, and 40-meter bands.

Even though ion production in the D, E, and lower F regions is lower, ions are better able to diffuse and drift upward along the geomagnetic field lines into the F region. This layer is the major factor in defining the maximum usable frequency and maximum on each side of the geomagnetic equator, as shown in my October, 1983, column. These maximums, which are reached most evenings at about 2200 local time, eliminate one whole earth bounce and its accompanying double-D region transits for one-long-hop propagation.

The fifth characteristic of winter DX conditions — the increased stability of signal strengths and the decrease in the number and intensity of geomagnetic field disturbances — is attributable to the eccentricity of the Earth's orbit. When the Earth is closer to the sun, the solar flux pressure on the magnetosphere surrounding the earth tends to hold the magnetosphere steadier. This means that the geomagnetic field is least disturbed during November and December. This manifests as least variation of the magnitude and direction of the geomagnetic field lines in an hour's time, translating into fewer periods of QSB during these months.

last-minute forecast

The higher-frequency bands are expected to be best during the first two weeks of the month because of the probability of higher solar flux at that time. The new 11-year solar cycle is also expected to be well underway, with higher solar flux from the more active regions. More potent geomagnetic storms may accompany this increased activity, but they're not really expected during this quiet time of the year and at this point in the sunspot cycle. The most probable times of the month are November 2, 11, and 20. The lower bands are expected to be best the third week of the month. Thanksgiving weekend should be a good one for the whole frequency range.

The Taurids meteor showers will occur from October 26 to November 22, with a maximum count of ten per hour from the 3rd through the 10th of November. Lunar perigee is on the 5th.

band-by-band summary

Ten and twelve meters, the highest day-only DX bands, are nearest the MUF for southern hemisphere paths. They will be open most days when the solar flux is above 75 during the 3- to 5-hour period centered on local noon. These bands open on paths toward the east and close toward the west. The paths are up to 4000 km (2400 miles) in single-hop length, and on occasion double that during evening transequatorial openings.

Fifteen meters, a day-only DX band open most of each day, has lower signal strengths and greater multipath variability than 10 and 12 meters. It will be best when the MUF is resting just above this band, until it drops below it — a transition period that occurs

NOVEMBER

WESTERN USA

GMT	PST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	4:00	40	40	20	15	15*	12	12	20
0100	5:00	30	40	20	15	15	12	12	20
0200	6:00	30	40	20	20	15	15	15	20
0300	7:00	40	_40_	30	20	20	15	15	30
0400	8:00	40	_40_	30	20	20	20	20	30
0500	9:00	40	_40_	30	20	20	20	20	40
0600	10:00	40	_40_	30	_20_	20	20	20	40
0700	11:00	40	_40_	_30_	_30_	20	20	20	40
0800	12:00	40	_40_	_30_	_30_	_20_	_20_	30	40
0900	1:00	40	_40_	_30_	_30_	_30_	_30_	30	40
1000	2:00	40	_40_	_30_	_30_	_30_	_30_	_30_	_40_
1100	3:00	_40_	_40_	_30_	_30_	_40_	_30_	_30_	_40_
1200	4:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
1300	5:00	_40_	30	20*	20*	_30_	_30_	_30_	_40_
1400	6:00	_40_	20	15	15	20	_30_	_30_	_40_
1500	7:00	_40_	20	15	15	15	20	20	_40_
1600	8:00	40	20	15	12	15	20	20	_40_
1700	9:00	40	20	12	12	15	20	_30_*	_40_
1800	10:00	40	30	12	12	15	15	20	_40_
1900	11:00	40	40	12	12	15	15	20	_40_
2000	12:00	_40_	40	15	10	15	15	15	20
2100	1:00	_40_	40	15	10	15	12	15	20
2200	2:00	_40_	40	15	12	15	12	15	20
2300	3:00	_40_	40	20	12	15*	12	15*	20

MID USA

MST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN	CST
5:00	40	40	20	15	15	15*	12	40	6:00
6:00	40	40	30	20	20	12	12	40	7:00
7:00	40	40	30	20	20	15	15	40	8:00
8:00	40	_40_	30	20	20	15	15	40	9:00
9:00	40	_40_	30	20	20	20	20	40	10:00
10:00	40	_40_	30	_20_	20	20	20	40	11:00
11:00	40	_40_	_30_	_30_	20	20	20	40	12:00
12:00	40	_40_	_30_	_30_	_20_	20	20	40	1:00
1:00	_40_	_40_	_30_	_30_	_30_	_20_	30	_40_	2:00
2:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_	3:00
3:00	_40_	_40_	_30_	_30_	_40_	_30_	_30_	_40_	4:00
4:00	_40_	30	_30_	_30_	_30_	_30_	_30_	_40_	5:00
5:00	_40_	20	20*	20*	_30_	_30_	_30_	_40_	6:00
6:00	_40_	20	15	15	20	_30_	_30_	40	7:00
7:00	30	20	12	15	20	20	20	40	8:00
8:00	30	20	12	15	15	20	20	40	9:00
9:00	40	20	12	12	15	20	_30_*	_40_	10:00
10:00	40	20	12	12	15	15	20	_40_	11:00
11:00	40	20	10	12	15	15	20	_40_	12:00
12:00	40	30	12	12	15	15	15	_40_	1:00
1:00	_40_	40	12	10	15	15	15	30	2:00
2:00	_40_	40	15	10	15	12	15	20	3:00
3:00	_40_	40	20	12	15*	12	15	20	4:00
4:00	_40_	40	20	15	15*	12	12	20	5:00

EASTERN USA

EST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE CARIBBEAN S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
7:00	40	40	20	20	15	15	15	40
8:00	40	40	30	20	20	20	20	40
9:00	40	_40_	30	20	20	20	20	40
10:00	40	_40_	30	20	20	20	20	40
11:00	40	_40_	_30_	20	20	30	30	40
12:00	_40_	_40_	_30_	_20_	20	30	_30_	40
1:00	_40_	_40_	_30_	_30_	_20_	_30_	_30_	40
2:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
3:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
4:00	_40_	_40_	_30_	_30_	_30_	_30_	_30_	_40_
5:00	_40_	30	20*	_30_	_30_	_30_	_30_	_40_
6:00	30	20	15	20	_40_*	_30_	_30_	_40_
7:00	30	20	12	15	20	20	20	40
8:00	40	20	12	15	20	20	20	40
9:00	40	20	12	15	15	20	20	40
10:00	40	20	10	15	15	20	20	_40_
11:00	40	20	10	12	15	20	20	_40_
12:00	40	20	10	12	15	20	_30_*	_40_
1:00	40	20	12	12	15	15	20	_40_
2:00	40	30	12	10	15*	15	20	_40_
3:00	40	40	15	10	15*	15	15	30
4:00	_40_	40	15	12	15*	12	15	20
5:00	_40_	40	20	12	15	12	15	20
6:00	_40_	40	20	15	15	12	15	20

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

right after sunrise and just before sunset. Transequatorial openings will occur, with distances similar to 10 and 12 meters.

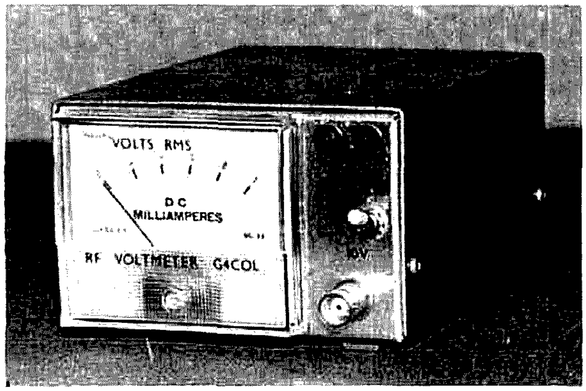
Twenty, thirty, and forty meters are both daytime and nighttime DX bands. Twenty is the maximum usable band for DX in the northern directions during the day. In combination with 30 meters, it provides nighttime paths for the day-only bands. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30 meters. This path may be affected by anomalous absorption during a few days of the month.

Eighty and one-sixty meters, the night-only DX bands, exhibit short-skip propagation during daylight hours, then lengthen at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas for a few hours before dawn. Remember the DX windows of 3790 to 3800, 1825 to 1830, and 1850 to 1855 kHz.

ham radio

an rf voltmeter

Don't let its apparent simplicity fool you — this instrument has many uses



Many of us who experiment with circuits need to measure the level of signal sources such as oscillators, amplifiers and multipliers in transmitters, and local oscillator systems in receivers. The voltmeter design described in this article came about when I wanted to measure the voltage reflection coefficient of antenna systems using a return loss bridge at low levels so as not to interfere with other band users.

The common method of measuring signal levels is through the use of a simple diode detector. In its basic form, however, it has a number of shortcomings, some of which can be easily overcome.

voltmeter requirements

This voltmeter covers a range from less than 70 millivolts to greater than 3 volts rms (equivalent to -10 to $+23$ dBm in a 50-ohm system), covers a frequency range from 10 kHz to 150 MHz, and provides readings accurate to within ± 2 dB without calibration — i.e., as built and tested. Its input impedance is set by the input resistor; a value of 50 ohms was used in the models shown. Its output is linear; if an analog meter is used, no special marking of the meter scale is necessary. An external general-purpose meter can also be used. The meter draws less than 15 mA from a pair of 9-volt transistor batteries.

diode detectors

The characteristics of an ideal linear voltage detector are illustrated in **fig. 1**. This mythical device conducts current in one direction only, with a low and constant resistance when forward biased and an infinite resistance in the reverse direction. The constant forward resistance is maintained right down to 0 volts,

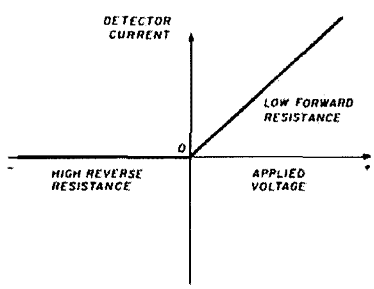


fig. 1. Ideal detector characteristics.

By Ian Braithwaite, G4COL, 28 Oxford Avenue, St. Albans, Herts, AL1 5NS, England

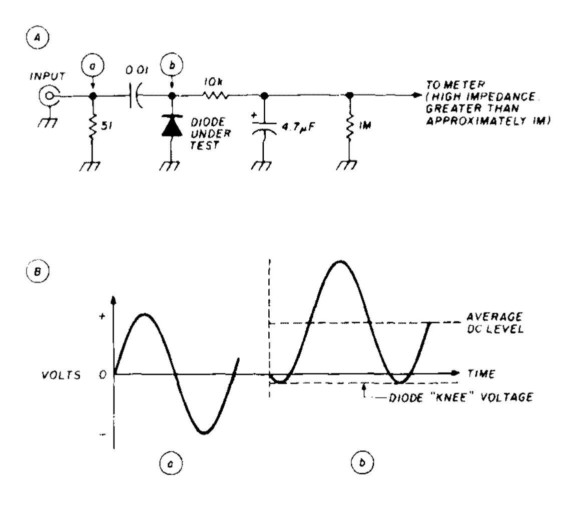


fig. 2. Unbiased single diode detector: (A) schematic (B) waveforms at "a" and "b."

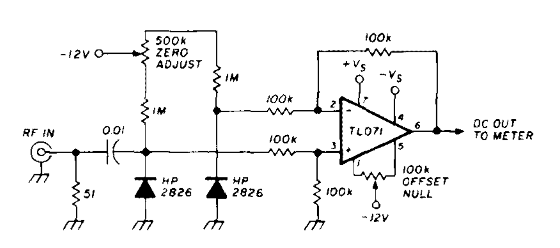


fig. 3. Two-diode biased detector.

with an abrupt transition to the reverse region. Such a device used as a rectifier would deliver a dc output proportional to the applied ac.

Real diodes, however, don't behave this way. Most do not conduct appreciably in the forward direction until the input voltage across them exceeds a threshold or "knee" voltage, which for an ordinary silicon junction diode is around 0.7 volts. The threshold voltage for germanium and Schottky diodes is lower — 0.2 to 0.4 volts. Real diodes also conduct slightly in the reverse direction (the so-called reverse leakage current).

The transition between the conducting and nonconducting states is not sharp, but occurs over a region where the diode is said to have "square law" behavior and the dc output is proportional to the applied *power* (voltage squared), rather than the signal voltage. This is used to advantage in low-level diode power meters.

To see how real detectors behave, I made some measurements on a few types using a crystal oscillator signal source at 10 MHz, and a power meter and attenuator to give a range of calibrated levels. **Figure 2** shows the first test circuit, a simple peak detector using an HP2826 Schottky diode. The right-hand plate of the input capacitor is clamped at the diode knee voltage below ground on negative input swings. If this knee voltage were actually zero, the average voltage on the diode would equal the peak of the input voltage, but the real diode produces less. The resistor and capacitor filter the rf present on the diode, leaving the dc component. This can be measured by a high impedance meter which reads the peak of the rf voltage minus the diode knee voltage.

A dc forward bias current can be used to improve the sensitivity of the diode detector. If the diode is fed from a high resistance with a current of a few μA, its forward junction voltage will sit around the knee voltage. This potential no longer has to be supplied by the rf, which sweeps the diode's nonlinear characteristic and is detected. Direct current bias is used in the more sophisticated circuit shown in **fig. 3**. Two diodes are used. Both are biased, but rf is fed to only one of them. An op-amp subtracts the diode voltages so that the output of the circuit can be set to zero in the absence of an rf signal. With the diodes connected together, with no rf, the op-amp offset is nulled. The 500-k pot is then adjusted to give zero output with the circuit exactly as drawn. The circuit works best with matched pairs of diodes, since these track well with temperature.

The performance of these detectors is described graphically in **fig. 4**. This shows the improvement in sensitivity achieved with bias. Also shown is the curve for the voltmeter design, which indicates further improvement in sensitivity and linearity, gained by using just one additional technique.

The complete rf voltmeter is shown in the block diagram in **fig. 5**. Two detectors are used. One receives the incoming rf signal, while the other, a "mimic" detector, is fed with a low frequency signal. This signal is an internally generated sinusoid, derived by chopping the dc output of an integrator to give a square wave which is then filtered, leaving the fundamental frequency component.

The integrator input is the difference of the two detector voltages, and its output will change (or "slew") when this difference (the feedback loop's error signal) is other than zero. The action of the negative feedback loop around the mimic detector in fact causes the integrator to try to achieve this zero-error condition, at which point, if the detectors are well matched, the low frequency signal will have the same amplitude as the rf signal. Because the low frequency signal is produced by chopping and filtering the integrator's dc output, this latter voltage is proportional to the rf input voltage, and can be scaled and metered to provide readings in "rf" volts.

Through the use of well-matched and closely spaced

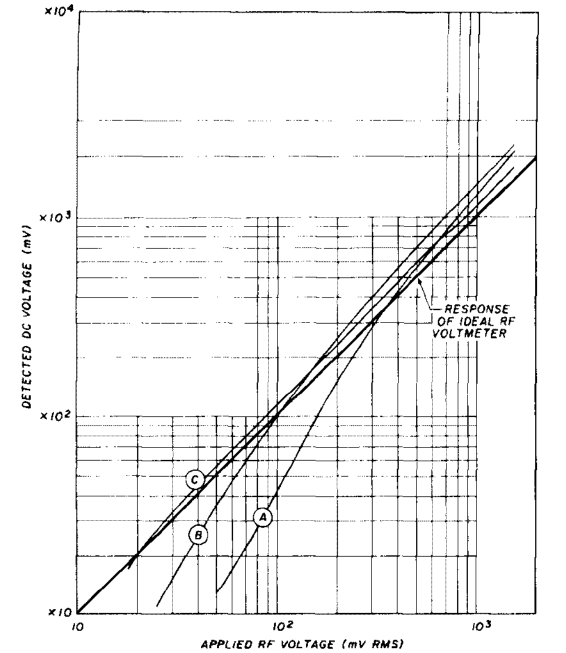


fig. 4. Detected dc output versus applied rf input: (A) single unbiased diode detector; (B) biased diode detector; (C) rf voltmeter; (D) ideal rf voltmeter.

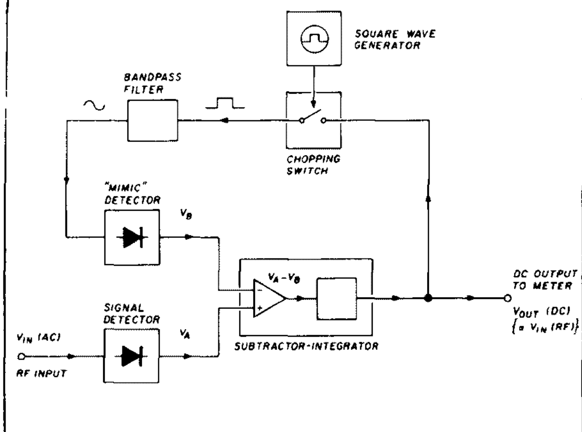


fig. 5. Voltmeter block diagram.

diodes, their temperature and I-V curve variations are minimized. Of course, since the mimic detector measures only a fixed low frequency signal, no frequency response compensation for the input detector is provided. Therefore, it's best to choose the diode that has the flattest possible response.

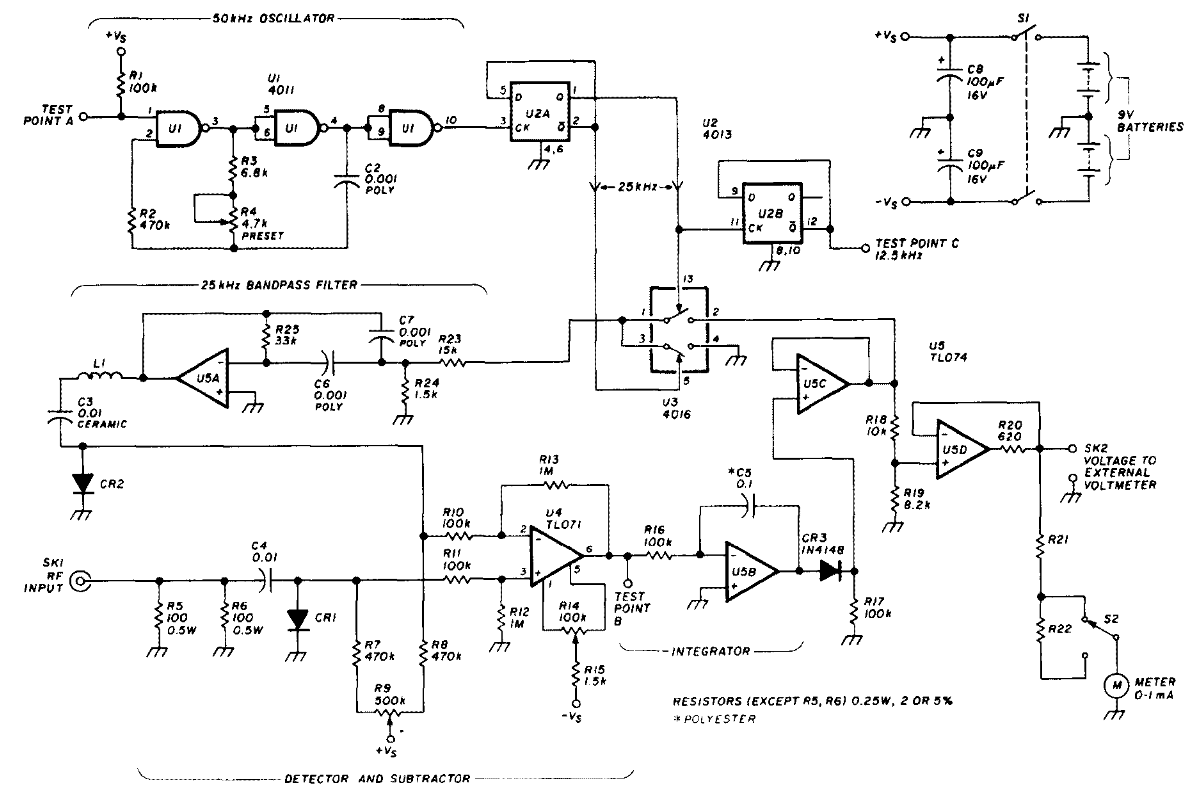


fig. 6A. Voltmeter schematic diagram.

circuit description

RF enters the instrument via socket SK1. R5 and R6 provide a good impedance match to 50-ohm cable. Two 0.5-watt metal film resistors (or any other combination providing 50 ohms and a 1-watt rating) should be used. Diodes CR1 and CR2 form the detectors: CR1 is supplied with rf, and CR2 with the internally generated 25-kHz sine wave. They should be Schottky diodes and, if possible, should be reasonably well matched in terms of forward voltage at around 10μA. Many types will do, among them the HP2800 and 2826 and the Thomson BAR28. The forward voltage will be in the region of 250 mV, and a pair matched to within a few millivolts can often be found from a small batch. Circuitry around U4 performs subtraction of the two detector outputs with a gain of 10. R14 allows U4's offset voltage to be nulled. Because this is a relatively high gain stage, the remaining stages do not need to be nulled, and can be grouped into a quad package. U5B is wired as an integrator, and CR3 and buffer U5C prevent the CMOS switch U3 from being driven negative. The buffer's dc output is chopped by switch U3, which is operated by 25-kHz square waves from U2, a divide-by-2 flip-flop fed from U1, a 50-kHz oscillator. U2 could be omitted and U1 run at 25 kHz, but U2 does achieve a perfect square wave (1:1 mark-to-space ratio) at small cost. U2B provides a 12.5-kHz output signal so that a rough check can be made on the switching signal with a crystal earpiece at test point C. The chopped dc from U3, now a 25-kHz square wave with a peak-to-peak amplitude equal to the U5C dc output, is filtered by active filter U5A (second order bandpass) so that CR2 receives a fairly sinusoidal signal. L1 was included to stop hf oscillations in the output stage of U5A when the connection to the detector was completed via several inches of ribbon cable (the adjacent wire being grounded). It consists of four turns of enameled wire on a single-hole ferrite bead (I used an FX1115), and has no measurable effect at 25 kHz. R18 and R19, buffered by U5D, attenuate the dc by a factor of 0.45 (see **appendix** for derivation), which provides scaling to units of volts rms. An external voltmeter plugged into SK2 will then read the rf input voltage. R21 and R22 with switch S2 allow the use of a meter to read 1 and 10 volts full-scale. With 9-volt supplies from batteries, the maximum voltage that can be read will be around 3 volts.

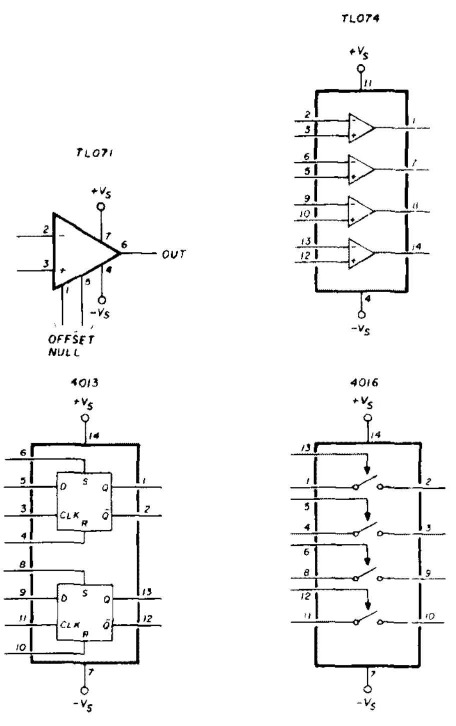


fig. 6B. Voltmeter integrated circuit pinouts.

construction

I have built three instruments according to the design described in this article (see **fig. 7**). The outer two are battery powered (internally); the "economy model" in the center uses an external power supply and meter. Details of the unit on the left are shown in **figs. 8A, 8B,** and **8C**. Construction is straightforward and can be done with ordinary hand tools. The only critical area is the detector, which carries rf. The other areas involve only low frequency circuitry. As shown in **fig. 8C**, I built the input circuitry, consisting of the two detector diodes and U4, on a small piece of double-sided, copper-clad glass-fiber board, using a counterbore tool to provide pads for the components. Frankly, this method of construction — with the components mounted rats-nest style above a copper ground plane, will work at least as well and probably better than a pc board, and is certainly much faster. Those willing to make a pc board for the voltmeter are welcome to do so — I'm afraid I'm too lazy!

The rest of the circuit is wired on a perforated breadboard with copper strips on the underside (known in the UK as "Veroboard"). As the photo of the detector board shows, the signal connection from the front panel socket was made using RG-178 coaxial cable. The only place it's important to keep leads as short as possible is in the detector area. Try to mount the two diodes close to each other for good thermal tracking.

alignment and testing

Check the 50-kHz oscillator and divider by placing a crystal earpiece or high impedance audio amplifier between test point C and ground. The frequency can now be adjusted to coincide with the bandpass filter.

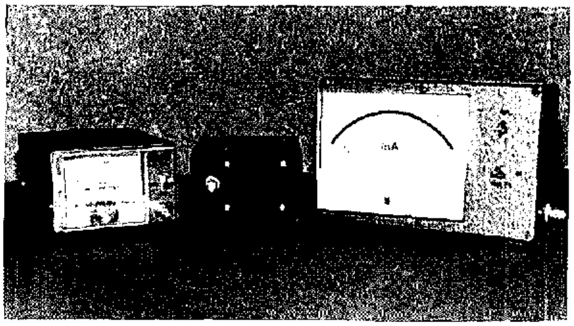


fig. 7. Three different packaging approaches for the same voltmeter.

Turn R9 or R14 so that U4 output is slightly negative, which will cause the integrator U5B to slew to the positive limit. This should result in a healthy square wave output from U3 (pins 1 and 2). A high impedance meter should read a voltage (dc) here that is half that at the U5C output. If the meter is transferred to the anode of CR2, it should be possible to peak this voltage by adjusting the oscillator frequency control R4.

The detector circuit can now be set up with no input. Ground test point A to stop the 50 kHz oscillator. Connect CR1 and CR2 so that the subtractor sees the same voltage at both its inputs. Set test point B to zero volts with R14. Remove the connection between the diodes, and again zero-test point B, this time with R9.

If rf is now applied, U5C should go positive, and the voltage at the output socket SK2 should be 0.45 of this. The meter is now ready to use.

performance

The absolute accuracy and linearity of this meter is illustrated in **fig. 4**, which was constructed from measurements made at 10 MHz. The flatness with frequency was measured at 1 mW, 224 mV rms (0 dBm), and the results are shown in **fig. 9**, which represents a respectable performance of within ±3 percent up to 150 MHz. This could no doubt be improved to extend the useful range to 70 cm and beyond.

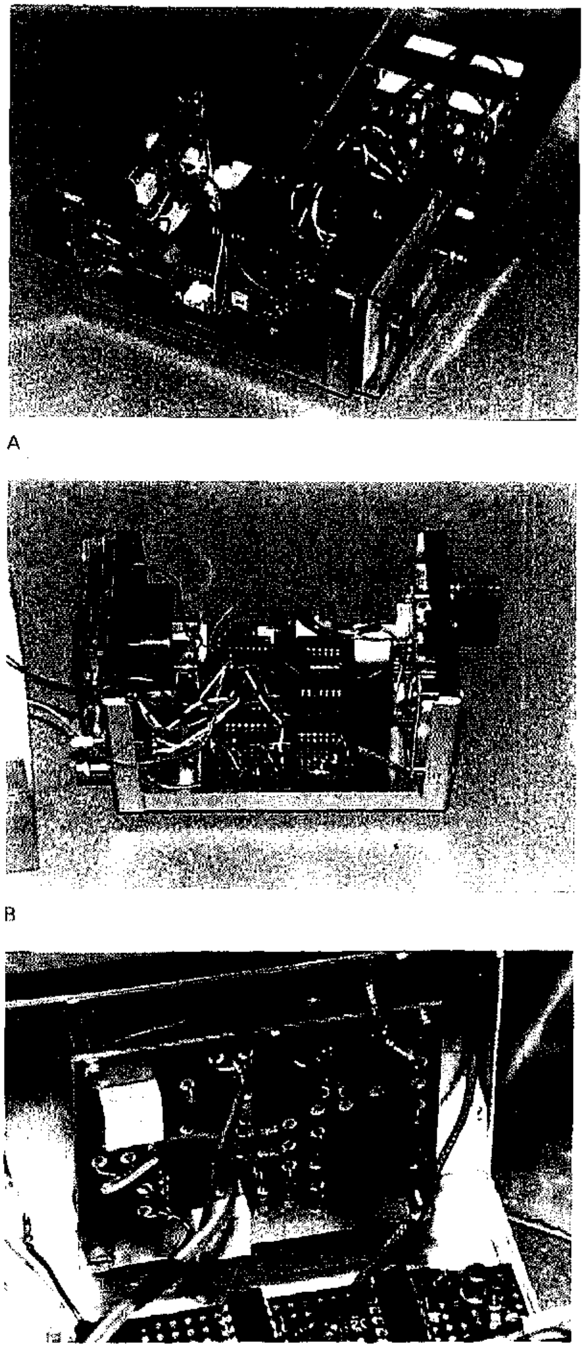
To verify the repeatability of these measurements, I tested the three units against each other using the same source, a 10-MHz crystal oscillator. Referring to the units by position in the photo, the results were:

Unit	Reading on external voltmeter
Left	268 mV
Center	244 mV
Right	258 mV

Obviously, three is only a small sample, but considering that the voltmeters had received only the simple dc setup procedure described earlier, I was quite pleased with the outcome, and I hope that this sort of performance will be adequate for your applications.

further suggestions

I hope that readers who build this voltmeter will find it a handy instrument to have around the shack. Those who like to experiment and develop their own hardware might enjoy exploring the following options:



A

B

C

fig. 8. Internal views of the rf voltmeter: (A) internal power provided by two 9-volt batteries; (B) "clean" construction enhanced by use of Veroboard; (C) "rf" section of voltmeter.

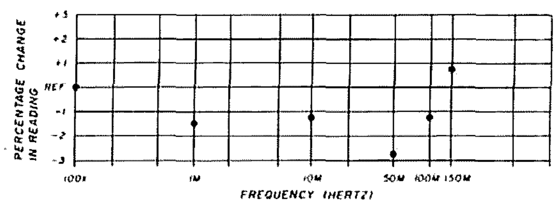
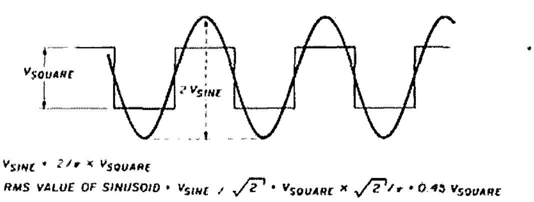


fig. 9. Flatness with frequency at 0 dBm.

• The design can be simplified by omitting the divider U2. The oscillator could then be run at 25 kHz, or the filter redesigned for 50 kHz. (The choice of frequency was somewhat arbitrary, being high enough to use small coupling capacitor C3 and low enough for active filtering. U2 does guarantee an excellent square wave, but the oscillator alone may well be adequate.)
• The detectors can be built into a high-impedance probe for circuit tracing, rather than a 50-ohm instrument. Keep CR1 and CR2 physically and electrically close together, though.
• By paying attention to the detector matching and circuit offsets, particularly around U4, the useful range could be extended downwards. With attenuators, the range could be extended upwards.
• Careful selection of devices and construction could greatly extend the frequency range.
• The filtering of the square waves could be improved. The units I have built tend to read slightly high, and this could be because the active filter output is not a pure sinusoid, giving a slightly wrong scaling factor. Why didn't I just feed CR2 with a raw square wave? Well, when I tested a diode detector using an accurate function generator, the peak readings were different between sine and square waves — i.e. the diode appeared to clamp at slightly different voltages, depending on the waveform. I wish I knew why; in any case, the results might be worth repeating. If CR2 gave the same response to square waves, the active filter could be omitted. U5C output would then be the peak input voltage, and scaling by 0.707 would give readings in volts rms.



$V_{SINE} = 2/\pi \times V_{SQUARE}$

RMS VALUE OF SINUSOID $= V_{SINE} / \sqrt{2} = V_{SQUARE} \times \sqrt{2}/\pi = 0.45\, V_{SQUARE}$

fig. A1. Relationship between a square wave and its fundamental sinusoidal component.

appendix

how readings are scaled to volts rms

The voltmeter works by making an internally generated sine wave derived from filtering a square wave equal to the rf input. The square wave, then, is generated by chopping a dc voltage. As illustrated in **fig. A1**, Fourier theory tells us that the fundamental (sinusoidal) component of a square wave has a larger peak amplitude than the square wave itself (don't worry, there is less power in this sine wave). If we call the peak amplitude of the sine wave V_{sine} and the peak-to-peak amplitude of the square wave V, then;

$$V_{sine} = \frac{2V}{\pi}$$

But in the voltmeter circuit, the peak-to-peak square wave amplitude is equal to the integrator's dc output voltage V_{dc}, that is:

$$V = V_{dc}$$

We want to make the voltmeter read rms volts. If the applied rf has an rms voltage V_{in}, then the feedback loop makes:

$$V_{sine} = \sqrt{2}\ V_{in}$$

So, the quantity we want to measure, V_{in} is given by:

$$V_{in} = \frac{V_{sine}}{\sqrt{2}} = \frac{\sqrt{2}\ V_{dc}}{\pi} = 0.45\ V_{dc}$$

This is why the dc produced by the integrator is scaled by 0.45.

ham radio

VHF/UHF WORLD

Joe Reisert
W1JR

low-noise receiver update: part 1

"You can't work 'em if you can't hear 'em" is an old adage that's still very true. Building bigger and better antennas helps, but sooner or later the antenna size limitation places the burden on the receiver.

Only a decade ago, most Amateurs were using bipolar transistor preamplifiers on the front ends of their VHF and lower UHF band receivers. On the upper UHF and lower SHF bands, diode mixers without preamplifiers were common — with typical noise figures of 6 to 10 dB! That's all changed now, first with the arrival of low-noise silicon bipolar transistors capable of operation into the GHz region, and then with the introduction of GaAs (Gallium Arsenide) FETs in the late 1970s.[1]

Since reference 1 was written, there have been many new and startling developments in the area of low-noise devices and techniques. Noise figures are still dropping; device prices have stabilized. So this seems like an appropriate time to update the earlier material and to present state-of-the-art (SOA) information.

This month's column will serve as a quick review and update of the present SOA in low-noise receiver technology. Next month's column will be devoted more to low-noise circuit techniques, recommended devices, testing, and optimization. With all this information in place, you should be right on the cutting edge of low-noise receiver technology.

a quick review

The SOA in VHF/UHF and microwave low noise figure Amateur receivers and preamplifiers is now dominated by GaAsFETs, which are technically classified as Metal Semiconductor FETs (MESFETs). The term MESFET is used in the professional community because the gates of a GaAsFET are formed using aluminum, which is a metal that is in direct contact with the semiconductor material. Thus a Schottky barrier diode is formed in the N-type material as shown in **fig. 1A**.

When the lowest noise figure is required above about 100 MHz, GaAsFETs are favored over silicon bipolar transistors because they have up to five times faster electron mobility. Hence, GaAsFETs have much higher cutoff frequencies and gain than silicon bipolar transistors. Furthermore, they typically have much lower noise figures.

Reference 1, an introduction to low-noise GaAsFET technology, gave details on preamplifier designs for 144, 220, and 432 MHz, with suggestions for higher-frequency operation. When this material was published in 1984, the GaAsFET was king, but that's no longer true; lower-noise devices and new breakthroughs in technology now threaten to decrease noise figures so far that they will no longer be the primary limitation to communication capability. Stay tuned.

In addition, during the last few years there's also been a proliferation of "mast-mounted" low-noise preamplifiers using GaAsFETs. These preamps almost completely eliminate the losses associated with feed lines, and virtually eliminate the mismatch loss associated with feed line losses.[2] This is a major problem with low-noise preamplifiers because they often have high input VSWR.

latest developments in devices

GaAsFETs were originally used in commercial and government low-noise amplifiers operating above 2 GHz. Amateurs were in the forefront of developing low-cost GaAsFET preamplifiers to frequencies as low as 30 MHz, but these devices were practical mainly on 2 meters and above, where ambient and sky noise are low.[3]

GaAsFETs are now being used commercially through 40 GHz and possibly

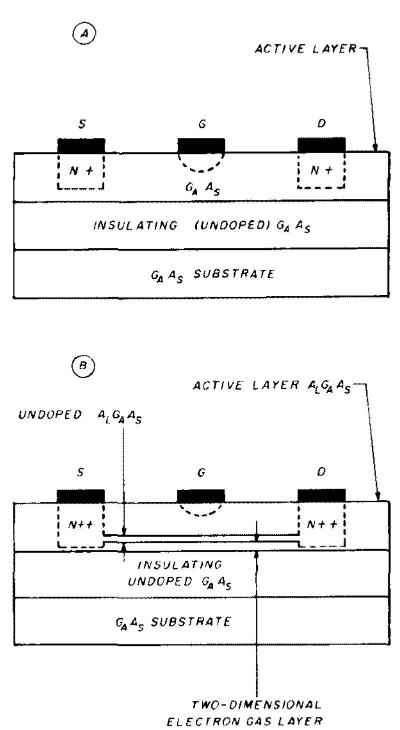


fig. 1. Typical physical structures (not shown to scale) of GaAsFETs and HEMTs: (A) depletion mode GaAs FET; (B) depletion mode HEMT.

higher. New lower noise figure, higher gain, and cutoff frequency devices seem to be appearing almost monthly. Needless to say, if you want to be on the cutting edge of technology, you might as well use any premium-quality devices you have in your desk drawer as soon as possible — before they become obsolete! GaAsFETs with noise figures less than 1.0 dB are now available through 4.0 GHz! SOA GaAsFET noise figures versus frequency are shown in **fig. 2**.

Probably the most important recent improvement in the SOA in low-noise devices is the development of the HEMT (high-electron-mobility transistor).[4,5] Sometimes referred to as TEGFETs (two-dimensional electron GasFETs)[6] or heterojunction FETs (to avoid infringing the copyright on the name HEMT in Japan). Technically speaking, the HEMT is a heterojunction superlattice device that was first described in 1978 and demonstrated by Fujitsu and Thompson-CSF in 1979.[4,5,6] It is very similar in structure to the GaAsFET except for the two-dimensional electron gas as shown in **fig. 1B**.

The HEMT's major feature is, typically, its higher transconductance with a cutoff frequency twice that of a comparable GaAsFET, with higher gain and noise figures as low as half those of typical GaAsFETs! Cutoff frequencies well above 100 GHz have been reported. HEMTs with less than 1.0-dB noise figures are now available through X band (12 GHz). The SOA in HEMT noise figures is shown in **fig. 2**.

Right now, however, most HEMTs are laboratory devices, and the lowest noise devices are very scarce. Only a few HEMT types are available commercially, and these devices are expensive — typically more than $150 each! However, remember that GaAsFETs were in the same price range in the mid-1970s, and better devices are now available for less than $5! HEMTs are known to be manufactured by Fujitsu, GE, Gould-Drexel, NEC, Sony, Thompson-CSF, Toshiba, TRW, and Varian Associates. Other suppliers and even lower noise figures are promised!

Unlike other innovations in technology, the HEMT is compatible with existing GaAsFET dc biasing and rf characteristics. HEMTs usually use the same packages and can be virtual "drop-ins" for GaAsFET circuits. The primary difference is that the HEMT's optimum source impedance is generally higher than an equivalent GaAsFET's. Therefore, an adjustable input-matching circuit similar to the one described in reference 1 is recommended so that the optimum source impedance can be achieved.

One major MESFET anomaly should be stressed. As pointed out in reference 1, GaAsFETs (as well as HEMTs) have a very high noise figure in the so-called $1/f$ or low-frequency region. This

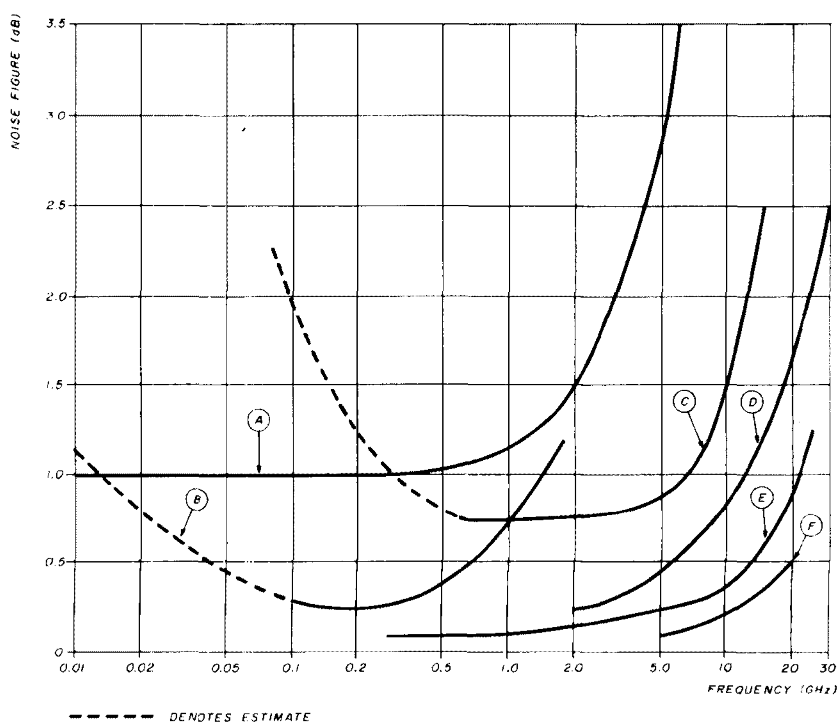


fig. 2. Typical 1987 state-of-the-art noise figures of bipolar transistors, GaAsFETs, and HEMTs: (A) uncooled bipolar transistor; (B) low-frequency GaAsFET at room temperature; (C) high-frequency GaAsFET at room temperature; (D) HEMT at room temperature; (E) GaAsFET cooled to 12 degrees Kelvin; (F) HEMT cooled to 12 degrees Kelvin.

means that the noise figure increases not only as you increase frequency, but also as frequency is decreased! This effect is shown in **fig. 2**.

The amount of noise figure increase and the frequency where it begins to increase (below the normal operating frequency) depends on the device type. Generally speaking, the ideal rf operating region for GaAsFETs and HEMTs is over a one decade-wide frequency range referenced down from the specified operating frequency (not the F_{max}).

For example, a device specified for 1-GHz operation at the top of its operational frequency range will probably be well suited for operation down to about 100 MHz. However, a device specified for 10 GHz will probably have a higher noise figure if it's used much lower *than* about 1 GHz!

Therefore, don't expect that a very low-noise GaAsFET specified for 10 GHz will be a super low-noise device at 144 MHz. A low-noise 10-GHz HEMT may well have a higher noise figure at 432 MHz than a much less expensive device specified for operation through 4 GHz. This is why so many Amateurs have been able to demonstrate incredibly low noise figures on 2 meters using GaAsFETs costing no more then $5 to $10!

Also, the higher the cutoff frequency of a GaAsFET or HEMT, the narrower the gate; hence, the susceptibility to static burnout increases. Furthermore, higher frequency devices are more prone to oscillate when operated at lower frequencies. So don't "read into the specifications" anything that isn't there. For optimum performance versus cost, operate MESFETs in the frequency range recommended by the supplier.

noise figure limitations

I'm often asked the question, "What limits noise figure?" It should be intuitive that part of the limitation on noise figure is in the actual device itself. Furthermore, for the lowest possible noise figure in a receiver, the gain of the first stage must be high and the second stage should also have a low noise figure. This is shown mathematically by the following equation.[7]

$$F = F_1 + (F_2 - 1/G_1) + (F_3 - 1) / (G_1 \cdot G_2) + \cdots \quad (1)$$

where F is the overall noise factor of the receiver, F_1 is the noise factor of the first stage, F_2 is the noise factor of the second stage, F_3 is the noise factor of the third stage, G_1 is the numeric gain of the first preamplifier and G_2 is the numeric gain of the second preamplifier. Note that noise factor and gains are in numerics, not decibels, so they often have to first be converted from decibels to numeric values before using them in **eqn. 1**. After the final noise factor is determined, you'll probably want to convert noise factor back to noise figure using the following equation.

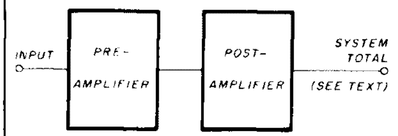
$$NF = 10 \log F \quad (2)$$

For example, refer to **fig. 3**, a block diagram of a typical Amateur front end. In example 1, if the noise figure of the first stage of a receiver is 0.5 dB (noise factor = 1.122), with a gain of 13 dB (gain = 20) and the second stage noise figure is 4.0 dB (noise factor = 2.51), with a gain of 15 dB (gain = 31.6) -- ignoring the third stage contribution and assuming it to be negligible) — the overall receiver noise figure will be 0.78 dB (noise factor = 1.197), a significant 0.28-dB increase over the first stage alone.

Now if we reduce the noise figure of the second stage to 1.75 dB (noise factor = 1.496) [example 2] or increase the gain of the first preamplifier to 8 dB (gain = 63) [example 3], the overall noise figure will be 0.59 dB (noise factor = 1.46), only 0.09 dB above the preamplifier alone, a small penalty to pay.

These calculations are often laborious and prone to error. For this reason, it's best to program **eqn. 1** and **eqn. 2** into a computer or scientific calculator to simplify the calculations and decrease the possibility of human error.[8]

Finally, don't get carried away with gain. Increasing the first stage gain too much may lead to intermodulation distortion or instability, thus limiting the



Example 1:			
Noise figure (noise factor)	0.5 (1.122)	4.0 (2.51)	0.78 (1.197)
Gain dB (gain in numerics)	13 (20)	15 (31.6)	28 (631)
Example 2:			
Noise figure (noise factor)	0.5 (1.122)	1.75 (1.496)	0.59 (1.146)
Gain dB (gain in numerics)	13 (20)	15 (31.6)	28 (631)
Example 3:			
Noise figure (noise factor)	0.5 (1.122)	4.0 (2.51)	0.59 (1.146)
Gain dB (gain in numerics)	18 (63)	15 (31.6)	33 (1995)

fig. 3. Block diagram of a typical Amateur front end showing the effects of tradeoffs in gain and noise figure (see text).

ability to use the inherent low noise figure.[9,10] Therefore, with the low cost of devices today, it's preferable to design for a reasonable first stage gain (15 to 20 dB) and use a similar type second stage with a moderate noise figure (1.0 to 2.0 dB typical). This provides an inexpensive and useful cost/performance tradeoff.

other noise figure limitations

Another noise figure limitation is incurred by operating a preamplifier at room temperature (more on this shortly). However, the major limitations on Amateur receivers attaining very low noise figures commensurate with device specifications are losses associated with the input impedance-matching circuitry.

Amateur preamplifiers are usually designed for a single frequency band. Typically the circuits employ some form of input tuning. This is a preferred technique since the input network will not only allow the device to be optimized for the lowest possible noise figure at the frequency of interest, but will also act like a filter and prevent strong out-of-band signals from entering or causing IMD.

Most Amateur preamplifier input circuits, especially below 500 MHz, use an inductor and capacitor tank circuit similar to those shown in **figs. 4A** and **4B**. **Figure 4A** has one less component, but it also requires the tap to be

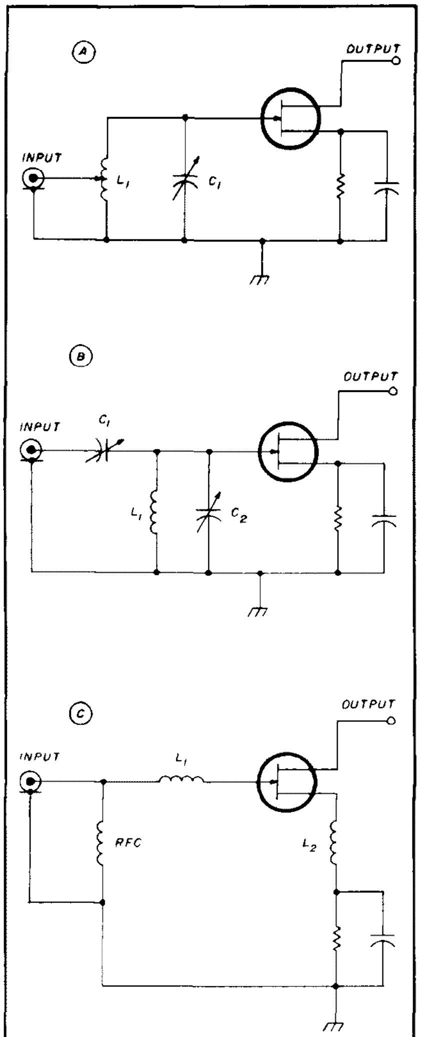


fig. 4. Some typical recommended input matching circuits for Amateur low-noise GaAsFET preamplifiers operating below 2.5 GHz: (A) tapped inductor; (B) capacitor transformer; (C) lossless feedback.

carefully chosen. This can be very tedious and time-consuming, especially if you want to achieve minimum noise figure. Therefore, the input impedance-matching circuit shown in **fig. 4B** is recommended for 500 MHz and below.[1]

Sometimes I see Amateurs and commercial designers alike using an abbreviated type of input matching similar to that shown in **fig. 4B**, but with the shunt capacitor, C2, removed. This is not recommended because if the lowest possible noise figure is wanted, the inductor also has to be tuned, and that can be a tricky job. (And what do you do for tuning if the GaAsFET has to be replaced?)

By now you've probably surmised that the minimum noise figure isn't only a function of tank circuit alignment, but more likely due to losses in the components themselves. All capacitors and inductors have loss, especially as you go above 100 MHz. The higher the Q of the components in the input-matching network, the lower the insertion loss and hence the lower the noise figure.

Probably the "lossiest" component in a low-noise preamplifier is the inductor. A typical inductor in the 100- to 500-MHz range has an unloaded Q (no external components attached) of 300 to 500, depending on wire type, diameter, form factor, and proximity of other components and shielding structure.[11]

As explained in reference 11, there's a definite insertion loss relationship between the unloaded Q_U of an inductor and the loaded or "in-circuit" Q_L of the same as follows:

$$\text{insertion loss (dB)} = 10 \log [1 - (Q_L/Q_U)]^2 \quad \textbf{(3)}$$

where Q_L and Q_U are the loaded and unloaded Qs, respectively.

How do you determine the loaded Q of the inductor? If the preamplifier is one of the types that uses a broadband output network as described in reference 1, the half-power or 3-dB bandwidth of the preamplifier can be easily measured. The Q of the preamplifier (and therefore the loaded Q of the inductor) is then determined as follows:

$$Q\ preamp = f_o/(f_H - f_L) \quad \textbf{(4)}$$

where f_O is the center frequency in MHz, f_H is the upper half-power frequency and f_L is the lower half-power frequency. For example, if we have a 432-MHz preamplifier with half-power frequencies of 440 and 423 MHz respectively, the loaded Q will be 432/(440 − 423) or 25.4.

Now, if we assume that all other components contribute negligible loss, we can determine the approximate input circuit losses attributable to the inductor's Q. Using **eqn. 3** and assuming a good inductor with an unloaded Q of 500 and a preamplifier with a loaded Q of 25.4, we have an input circuit insertion loss of approximately 0.45 dB.

Typical GaAsFET preamplifiers using input tank circuits of this type have noise figures of 0.5 to 0.75 dB. Therefore, with a 0.45-dB input loss, the overall noise figure of the preamplifier is almost entirely due to the losses in the input network and the GaAsFET itself must be virtually noiseless!

To show the Q_U/Q_L losses more graphically, I've prepared the graph in **fig. 5** and scaled it for low loss and hence low noise figure conditions. (Check **fig. 5** for the 432-MHz preamplifier case above.) For a Q_U/Q_L ratio of 500/25.4, or approximately 20, you'll see that the insertion loss is indeed 0.45 dB.

Also note in **fig. 5** that to get the input losses down below 0.1 dB, the unloaded-to-loaded Q ratio must be equal to or greater than 90. This means that the unloaded Q of the inductor in the preamplifier just described would have to be over 2000! If you want a very low-noise preamplifier, you're going to have to use some pretty low-loss inductors — such as a large (1- to 3-inch diameter) coaxial cavity resonator — and possibly have them silver plated.

Figure 4C is a different input circuit topology which eliminates the tank circuit per se by using a series input inductor and "lossless feedback" in the source lead.[1] This type of circuit definitely has lower input losses and potentially a better input VSWR. However, it's more prone to out-of-band interference and therefore is more appropriate for use on the microwave bands. It will be discussed further in next month's column.

other component losses

Don't forget that there can be other losses besides the input inductor. Tuning capacitors can also have losses. Only the lowest loss, highest Q tuning capacitors should be used in the

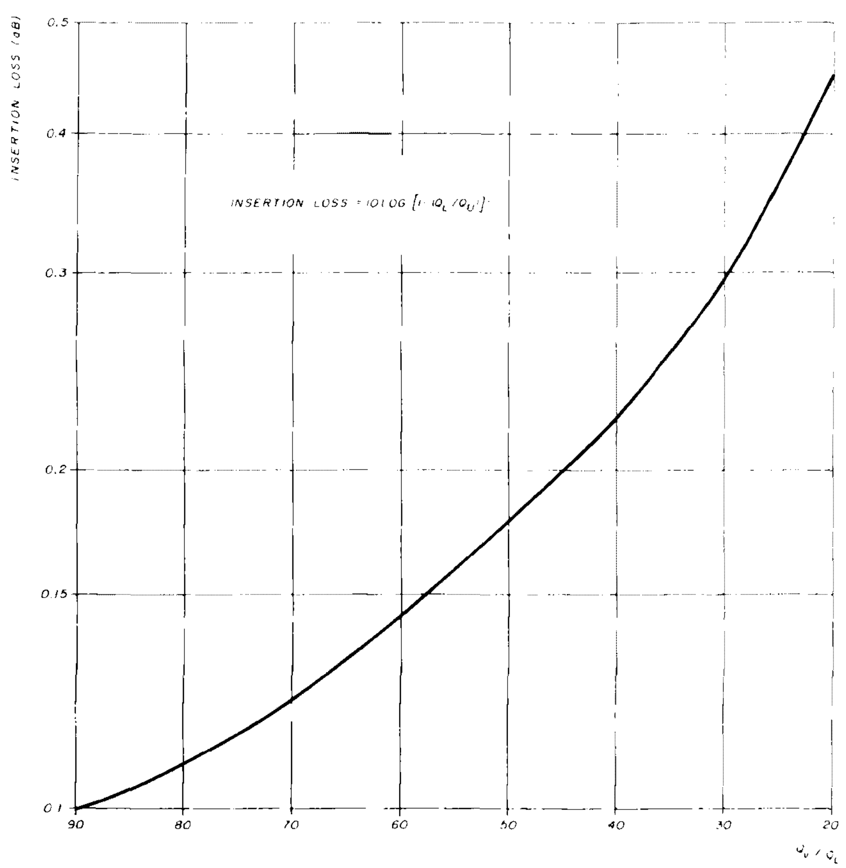


fig. 5. Insertion loss of an inductor (or capacitor) due to the effects of unloaded and loaded Q.

input-matching network. The air-variable type capacitors manufactured by Johanson and others are a preferred type. They not only have low loss and high Q, but also good tuning resolution with little or no backlash. Furthermore, they often have special sealing caps that can be placed over the tuning mechanism to help keep out moisture and prevent inadvertent mistuning.

The minimum Q of a Johanson-type 5200 air variable, one commonly used by Amateurs, is 5000 at maximum capacitance at 100 MHz. This figure decreases rapidly to less than 1000 above 300 MHz! Higher Q types such as the Johanson 5700 and 5800 are recommended, but they have lower maximum capacitance so they're useful only for higher frequencies and for series connections where lower capacitance values are required.

Chip capacitor losses can also be considerable, especially when used in source bypassing or in the rf path. In critical low-loss circuits, the porcelain types are highly recommended despite their higher initial cost. Be careful, too, of resistor types. The older 1/8- or 1/4-watt carbon composition types are recommended. However, the non-carbon or film types that are becoming so popular are usually quite reactive and lossy, and are therefore not recommended.

Finally, coaxial connectors — especially type N, TNC, and SMA — are highly recommended for low-noise preamplifiers because they have low loss and a very positive mating mechanism. On the other hand, BNC- and UHF-type connectors should be avoided because their impedance isn't constant, and they have questionable mating

tolerances and known insertion losses. Connector types and losses are discussed further in references 12 and 13.

lower noise techniques

Cooling is probably the last resort when it comes to really low-noise preamplifiers. Bipolar transistors generally don't work well below about 70 to 80 degrees Kelvin. However, many GaAsFETs and HEMTs seem to do quite well when cooled even as low as 12 degrees Kelvin, the temperature of liquified Helium.

The National Radio Astronomy Observatory (NRAO), in Charlottesville, Virginia, has been building low-noise preamplifiers for many years. Their preamplifiers are used in radio telescopes where the sky temperature is as low as 3.5 degrees Kelvin, almost absolute zero. By 1980 they were using GaAsFET preamplifiers cooled to about 13 degrees Kelvin in a Dewar with liquified Helium.[14]

At first NRAO used GaAsFETs because they noticed that the transconductance would often increase — sometimes by as much as 50 percent — as temperature was decreased. At the same time, the noise figure would drop. However, the optimum source impedance changes at low temperatures and oscillations may occur. Consequently the preamplifier has to be optimized at the cold temperature. Recently, NRAO noticed the same effects with HEMTs.

Because the cryogenic coolers used by NRAO cost about $5000 each, they're not really practical for Amateurs. Other less expensive coolers such as the thermo-electric type are available commercially.[15] However, they use diodes that may generate noise, so be cautious if you use them. It should be sufficient to mention that if you have an antenna-mounted preamplifier, especially for EME, you should mount it so that it won't be heated excessively by the sun.

Finally, of the GaAsFETs tested by NRAO, the MGF 1412 seems to have consistently low noise figure at room temperature. Futhermore, at cryogenic temperatures, the MGF 1412 type seems to be one of the most reliable for low noise figures. Since this is one of the most popular types used by Amateurs seeking the lowest possible noise figures, it may be a place to start.

summary

In this month's column, I've attempted to bring you up to date on the SOA in low-noise receivers for VHF and above. Noise figures are still dropping, but at some frequencies can't go lower unless we change the circuit techniques we're presently using. In next month's column, we'll discuss some circuit and device recommendations.

acknowledgments

I'd particularly like to thank Bill Lakatosh, AA4TJ (ex K3QCQ and KJ4QI), of NRAO for their input on SOA noise figures and cooling techniques.

new records

In last month's column we mentioned the outstanding sporadic E occurrence during the ARRL June VHF QSO party and asked for any new record claims. Shortly after the contest was over, I received and authenticated a new North American 2-meter, double-hop sporadic E record. The new record holders are Jim Poore, KD4WF, in Savannah, Georgia (EN92LK) and Jim Frye, NW7O/7, operating portable from Mount Potosi, southern Nevada (DM25GV). Their contact took place on June 14, 1987, at 1704 UTC and extended the existing record by almost 90 miles for a new record of 1980 miles (3186 km). Congratulations to both Jims.

The North American 10-GHz DX record has also been broken; more on that in next month's column.

important VHF/UHF events

November 3	Predicted peak of the Taurids meteor shower at 2200 UTC
November 3	Predicted peak of the Cassiopids meteor shower at 2200 UTC
November 14-15	ARRL EME Contest (second weekend)
November 17	Predicted peak of the Leonids meteor shower at 1500 UTC
November 21	New moon
November 24	EME perigee
December 13	Predicted peak of the Geminids meteor shower at 1900 UTC
December 20	New moon
December 21	± month. Winter peak of sporadic E propagation
December 22	Predicted peak of the Ursids meteor shower at 2200 UTC
December 22	EME perigee

references

1. Joe Reisert, W1JR, "VHF/UHF World: Low-noise GaAsFET Technology," *ham radio*, December 1984.
2. Joe Reisert, W1JR, "VHF/UHF World: Impedance-matching Techniques," *ham radio*, October 1987.
3. Joe Reisert, W1JR, "VHF/UHF World: Minimum Requirements for 2-meter EME: part 1," *ham radio*, August 1987.
4. John J. Berenz, "High Electron Mobility Transistors (HEMT)," *MTT-S*, Summer 1984.
5. John J. Berenz, "HEMT Technology Gains on mm-waves," *Microwaves and RF*, November 1985.
6. Henri Derewonko and Daniel Delagebeaudeuf, "Thompson Continues Work on 18-40 GHz 'TEGFETs,'" *Microwaves and RF*, November 1985.
7. Joseph H. Reisert, Jr., W1JAA, "Ultra Low-Noise UHF Preamplifier," *ham radio*, March 1975.
8. Joe Reisert, W1JR, and Gary Field, WA1GRC, "RF-CAD Electronics Design Program." (Available for IBM PC from *ham radio's* Bookstore, $39.50 plus $3.50 shipping and handling.)
9. Joe Reisert, W1JR, "VHF/UHF World: High Dynamic Range Receivers," *ham radio*, November 1984.
10. Joe Reisert, W1JR, "VHF/UHF World: High Dynamic Range on 2 Meters," *ham radio*, November 1985.
11. Joe Reisert, W1JR, "VHF/UHF World: The VHF/UHF Primer: An Introduction to Filters," *ham radio*, August 1984.
12. Joe Reisert, W1JR, "VHF/UHF World: RF Connectors — Part 1," *ham radio*, September 1986.
13. Joe Reisert, W1JR, "VHF/UHF World: RF Connectors — Part 2," *ham radio*, October 1986.
14. D. R. Williams, W. Lum, and S. Weinreb, "L-Band Cryogenically Cooled GaAsFET Amplifier," *Microwave Journal*, October 1980.
15. Charles A. Wheeler, "Cool It — for the Ultimate in Low-noise Amplification," *Microwaves*, April 1973, page 42.

ham radio

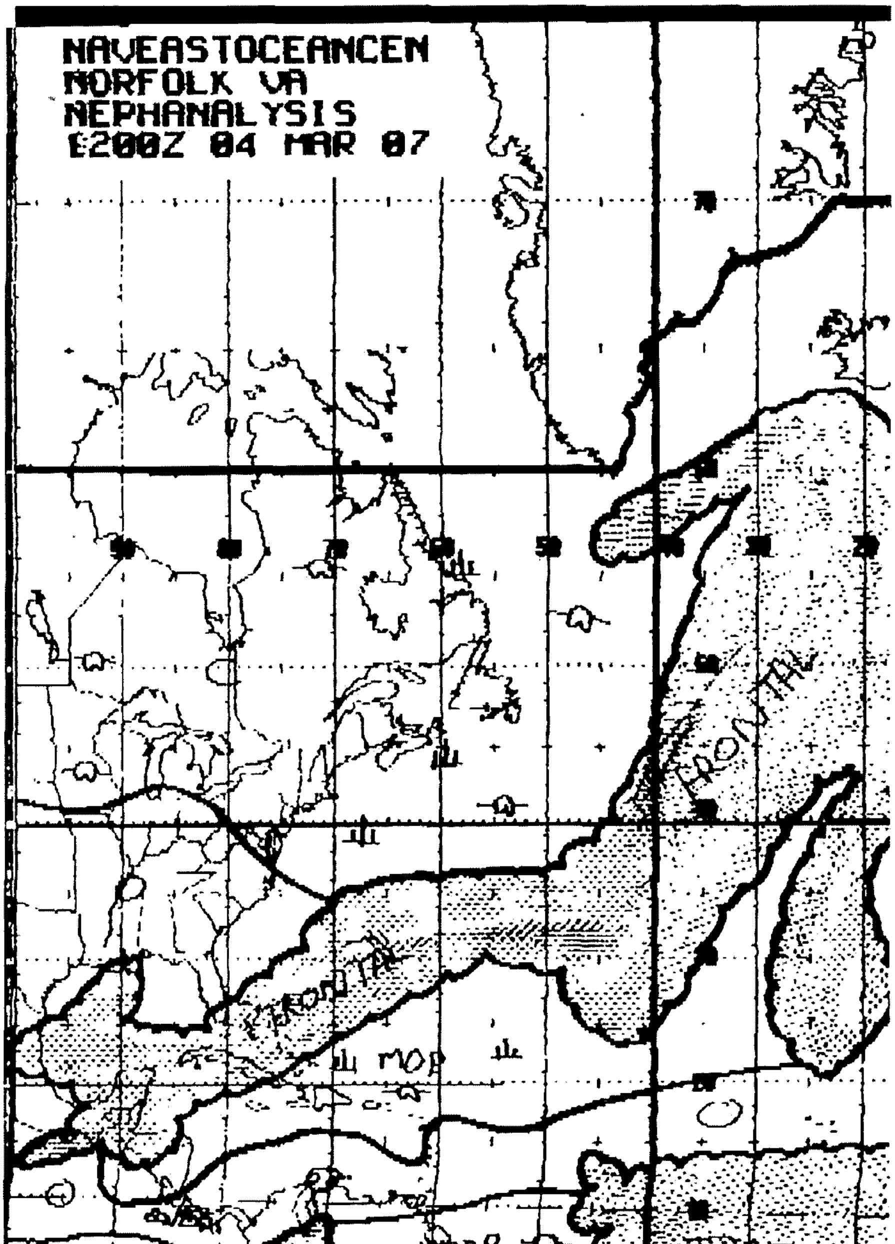
product

REVIEW

AEA weather FAX mod for the PK-232

Over the past few years, packet radio has grown from a rather esoteric part of Amateur Radio to one of the fastest growing segments ever. There must be at least ten manufacturers of TNCs, *all selling basically the same product.*

One way of selecting a TNC is to look closely at the features each unit offers. Do you want to go beyond packet? How about RTTY, AMTOR, ASCII, CW and weather FAX (WEFAX)? How about SIAM, Signal Identification and Acquisition Mode? If you want *all* these features in a single unit, your only choice is the AEA PK-232.



All currently manufactured PK-232s have the FAX and SIAM option installed. The unit we reviewed earlier (see page 81 of the July, 1987 issue) was one of the first units off the line and needed to be modified to work on WEFAX and SIAM.

When I learned of AEA's modification for WEFAX, I immediately called and placed an order for the kit. Because demand was enormous, it took a few weeks for my kit to arrive.

Besides the parts and instructions needed to perform the mod, AEA also supplied an addendum for the operator's manual and a pre-made computer-to-TNC to printer cable. The cable alone is more than worth the $40 price of the modification kit.

AEA is currently supporting most parallel graphics, and your dealer will have a complete list of printers that AEA has tested with the PK-232.

Four simple steps were all that were required to make the modification: remove the unit from use, disconnecting all cables; prepare a clean, static-free work area; remove six screws and open the unit; remove and replace EPROM U2 and install EPROM U3, then screw the cover back on. That's all there is to it. You're ready to reconnect and get back on line.

Sometimes it's hard to believe that the EPROM is as powerful as it is. Without EPROMS, the unit can't operate. Yet they can be installed in less than a heartbeat.

operation

I'll break this section into two parts: WEFAX and SIAM.

WEFAX. While WEFAX is basically a service for ships and aircraft, it offers a wealth of information for amateur meteorologists too. Stations transmit weather maps that show actual conditions and prognostications, satellite photographs of the earth's surface, taken from geosynchronous and orbiting satellites, and plenty of additional information. Of particular interest to me has been the hurricane maps that are sent during the hurricane season here on the East Coast.

Transmitting stations are located around the world, with each transmitting information for its own geographical area. Here in the Northeast, Halifax, Canada and Norfolk, Virginia provide the most reliable reception and information. I haven't had much luck with European or West Coast stations, but this is more a problem of time on the air and propagation.

The PK-232 represents the third generation of WEFAX equipment I've operated. Of the three units I've used, it's by far the easiest to set up and the most convenient to use. No special paper is required. There are no noxious fumes, the unit is easy to transport and install — it's really a pleasure!

From the time the modifications were finished, the cables installed, the computer hooked up and

product REVIEW

booted, to the reception of the first pictures, a grand total of 15 minutes passed.

Because you're using a dot matrix printer, you can't resolve shades of gray and therefore can't reproduce satellite images with pure photographic quality. The images, however, are very good and quite usable. Since maps and charts are black on white, their reproduction quality is excellent.

All you need to do is tune to a station transmitting FAX (with digital readout radios, tuning the PK-232 is no more complicated than subtracting 1.7 kHz from the transmitting station's published frequency). That's a heck of alot easier than it was with the old Hammerlund HQ-110's "coarse" and "fine" tuning controls. Then just configure the PK-232 to FAX mode, turn on the printer, and Bingo! Out come the maps and charts you've been waiting for.

You can also transmit FAX pictures. Frankly, because transmitting FAX requires a special program, I didn't try this option, so I can't comment on the PK-232's capabilities in this area. AEA is currently developing an MS-DOS program for FAX transmission. Details are too sketchy to report. However, early versions include FAX display on screen, transmission capabilities, and a number of other features. Availability is scheduled for late fall or early winter.

SIAM. One of the first things you notice when you tune across the hf bands is the variety of different digital signals. Even if you were an expert and could tell by sound alone, it would take time to configure the PK-232 to receive these signals. With SIAM, the PK-232 analyzes the signal and identifies the type of transmission and its speed. The operator can then decide whether to receive the station or continue on with a band search.

SIAM will decode a number of different digital codes: ASCII, ARQ, and FEC AMTOR and Baudot. It will also decode the Russian Cyrillic and Japanese Katakana codes.

To use SIAM, all you do is type in the command **OPMODE SIGNAL**, confirm that the receive (DCD) LED is lit, and wait approximately 10 seconds. The PK-232 will respond with a baud rate indication and a confidence of mode factor. In another 15 seconds, the PK-232 will identify the signal. To copy the signal, all you do is type in the command *OK*. If the SIAM analysis is correct, you'll start seeing text. If not, the PK-232 will give you a **?bad** prompt.

If the text is decoding but seems to be encrypted, you can try setting **BITINV** to **0** through 31, if only simple bit-inversion encryption is being used. If none of these 32 settings will decode the station, chances are another more sophisticated encryption system is being used.

conclusion

Typically, AEA has included a well written owner's manual that describes the operation of both WEFAX and SIAM modes fully. In case of difficulty, AEA has listed a number of common faults and the appropriate fixes. They also offer excellent advice by telephone if the manual and a little bit of work fail to solve the problem.

If you have a PK-232 and haven't yet modified it, you're missing out on a treat. I wouldn't just walk — I'd *run* to place the order!

AEA, 2006 196th Street SW, Lynnwood, WA 98036.

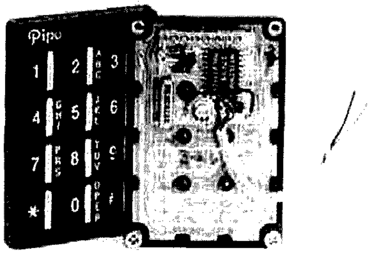
Circle #302 on Reader Service Card.

N1ACH

NEW products

miniaturized DTMF encoders

Pipo Communications has introduced the P-7 and P-8 series of miniaturized DTMF encoders designed for custom installation in radios or systems that are exposed to harsh or abusive environments. Built with steel keys and sealed gold dome contacts to ensure reliability and long life, the P-7 and P-8 encoders will fit most radios.



The P-7, a 12-key touchtone encoder, comes in vertical (P-7V) or horizontal (P-7H) formats measuring 2.16 inches by 1.5 inches by 0.20 inches. The P-8, a 16-key touchtone encoder, is available in a vertical (P-8V) format only; it measures 2.16 inches by 1.9 inches by 0.20 inches. Both are available in black or dark brown.

For more information, contact Pipo Communications, P.O. Box 2020, Pollock Pines, California 95726-2020.

Circle #303 on Reader Service Card.

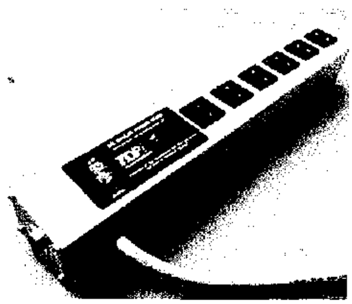
power strip spike protector

TDP's Model 10PS101 Power Strip Voltage Spike Protector has been specifically designed to guard solid-state circuits against potentially

damaging voltage spikes by absorbing and dissipating them through two 50-joule MOVs without interfering with normal current flow. All six outlets are circuit-breaker protected and rated at 15 amps.

In addition, the 10PS101 features a bi-directional noise filter to eliminate both RFI and EFI interference. The noise filter functions over a broad band (100 KHz to 20 MHz); high-frequency signals in this range are attenuated by up to 30 dB for improved equipment performance.

UL listed and American-made, the 10PS101 has six NEMA-type plug-ins and a heavy-duty,



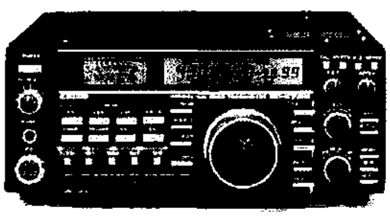
three-wire grounded 6-foot power cord. MOV working status is confirmed by a built-in indicator lamp.

For more information, contact TDP Electronics, 111 Old Bee Tree Road, Swannanoa, North Carolina 28778.

Circle #304 on Reader Service Card.

all-mode 440-MHz base station transceiver

ICOM has introduced the IC-475A 440-MHz base station transceiver. This deluxe all-mode base receives from 430 to 450-MHz and has 99 tunable full-function memories, passband tuning, a notch filter, noise blanker, built-in SWR bridge, semi or full CW break-in, and a multifunction meter. The new IC-475A also has a velvet-smooth tuning knob and easy-to-read amber LCD readout with variable backlight.



Four scanning systems are available: band, programmable, mode, and memory scan that scans 99 memories in five seconds, with selectable lock-out. The IC-475A features exciting new options such as a tone squelch unit, speech synthesizer, and OSCAR module that allows tracking with a companion IC-275A or IC275H;

NEW products

an FL-83 500-Hz, 10.749-MHz CW filter, and an AG-35 mast mounted pre-amp.

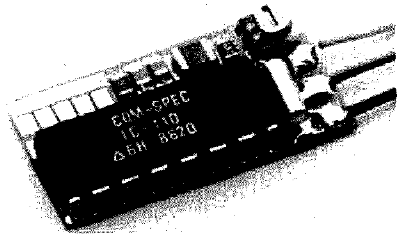
All subaudible tones are built in, and the actual subaudible frequency is displayed. Standard repeater splits are also built in, and odd splits are programmable. The 25-watt IC-475A is similar in design to ICOM's compact base station line: the IC-735, IC-275A, IC-275H and IC-575A.

The IC-475A is priced at $1,999.00. More information is available from ICOM America, Inc., 2380 116 Avenue N.E., P.O. Box C-90020, Bellevue, Washington 98009-9029.

Circle #305 on Reader Service Card.

CTCSS encoder

Communications Specialists of Orange, California has introduced a small programmable CTCSS encoder for use in handheld radios and other size-restricted applications. Dubbed the SS-32SMP, this new encoder measures only 0.53 × 1.00 × 0.16 inches, and offers full-tone versatility and high audio level.



Any 32 tone frequencies between 0.01 and 255.0 Hz may be selected for storage into a 32-bit EEPROM memory. These tone frequencies may be standard or non-standard, and may be changed at a later date if desired. The required tone frequency may then be selected by soldering binary coded jumpers on the tone board. The SS-32SMP may also be ordered to work as a six tone encoder (no switching diodes are necessary) at no extra charge. Multiple tone switching over six tones can be done with switching diode networks or a binary switch. Tone frequencies above 255.0 Hz may be ordered for a slight additional charge.

The SS-32SMP features a low-impedance, low-distortion, adjustable sine wave with adequate audio level to provide sufficient deviation for most handheld radios. It operates on 6 to 15 Vdc so that voltage dropping resistors should never be required.

Priced at $27.95, the SS-32SMP is covered by a one-year warranty and is available for immediate delivery from factory stock. A catalog is available on request; contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665-4296.

Circle #306 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance.** No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

TEST EQUIPMENT WANTED. Don't wait — we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at Skagitronics Co (800) 356-TRON.

"HAMLOG" COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7 band WAS/DXCC. Full features. Apple $19.95, IBM or CP/M $24.95. KA1AWH, POB 2015, Peabody, MA 01960.

RV OPERATORS are invited to check in Sun 2 PMC, 14.240 ± 5. Tues. Thurs 8 PMC 3.880 ± 5. Good Sam RV Net. Info SASE KJ4RO.

YAESU FT-727-R COMPUTER INTERFACE. For info write Gerald Hogsett Consulting, 1581 Woodland, Palo Alto, CA 94303.

NJ-NJ-NJ-NJ-NJ-NJ-NJ A Full-Service Ham-SWL-CB-Scanner store in NJ. Discount Grand Opening Prices. Top performing radio systems for every budget. New 10 meter and VHF/UHF rigs. ARRL, Amphenol, Astatic, Astron, Azden, B&W, Bilal Belden 9913, Butternut, Clear Channel, KLM, Larsen, MFJ, Mirage, Mil Spec Cables, much more. Open M-F 10 AM-9PM. Sat 10 AM-7 PM. Buy and sell used gear and have qualified repair facility. ABARIS SYSTEMS, 276 Oriental Pl, Lyndhurst, NJ 07071 (201) 939-0015.

CODE PROGRAMS. APPLE/C-64. 37 modes. LARESCO, POB 2018, 1200 Ring Road, Calumet City, IL 60409. 1-312-891-3279.

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

MEASURE VSWR, antenna patters, match circuit impedances from 100 kHz to 2 GHz with portable scalar network analyzers. Write for details. Direct Conversion Technique, 3132 North Lowell Avenue, Chicago, Illinois 60641 (312) 283-1690.

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521-5280.

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501 (714) 781-0252.

REMEMBER TROLLEY CARS? *Trolley Treasures: The Wartime Years in New Jersey* (1939-1947), a 4-volume photo-documentary history, includes 1600 unpublished, original photographs plus extensive historical notes. Volume I, *The Compromise Roof Cars of Public Service Coordinated Transport*, ready now. SASE for details. To order, contact Trolley Themes, A.W. Mankoff, 2237-3 Woodside Lane, Sacramento, CA 95825. ($14.95 plus $1.50 S&H).

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

BACK ISSUES HR Magazine from Vol. 1 No. 1 thru 1986, except 2 issues. $150for all postpaid. Also PopTronics, RE, 73 back to 1961. $15.00/full year. Write with your needs. Bill Fossman, 632 Wetmore, Everett, WA 98201.

MARCO: Medical Amateur Radio Council, Ltd, operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc.) invited to join. Presently over 550 members. For information write MARCO, Box 73's, Acme, PA 15610.

FOR SALE: ARCOS 2 meter K.W. RF deck using 8930 tubes. Unit was built by ARCOS then tested and not used since. RF deck, manual and blower all new. $650. Call NS9M at 317-832-2229, and leave message. Mark Pupilli, Box 117, Blanford, Indiana 47831.

HAM LAB PROJECT. Want several pieces HP G-382A variable attenuator. Will consider any repairable condition. K6GOX, PO Box 10, O'Neals, CA 93645 (209) 868-3548 Collect.

30 YEARS PROVIDING QSL's. Full color Old Glory, Cartoon. Also Parchment, Golden Eagle and others. Free samples. SASE appreciated. Rusprint, Rt 1, Box 363-HR, Spring Hill, KS 66083.

SUPERFAST MORSE CODE SUPEREASY. Subliminal cassette. $10. Learn Morse Code in 1 hour. Amazing new supereasy technique. $10. Both $17. Moneyback guarantee. Free catalog: SASE. Bahr, 2549-H7 Temple, Palmbay, FL 32905.

SAT TRAK II - A complete advanced self-contained satellite tracker with AZ/EL rotor control. Enter Keplerian data once via RS-232 with terminal or computer. Memory for 12 satellites. Accurate. Solid state AZ/EL drive. Available from ADR, PO Box 10184, Sarasota, FL 34230. (813) 378-3410.

TELESCOPE 10" Meade, drive motor, lens, like new $750. Trade TS-430, FT-757. K6KZT (805) 528-3181.

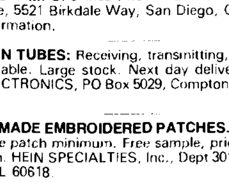
TEN-TEC, Now shipping new boxed USA made latest factory models, 561 Corsair II, 525D Argosy II, and Century 22 transceivers. RX 325 general coverage receiver, Model 2510 Mode B Satellite Station, TT920 Airband Aviation handheld transceiver, Model 229B 2 kw antenna tuner, Model 425 Titan 1.5 kw linear amplifier, plus accessories and antennas, also booking orders for Paragon delivery. For best deal, write or phone Bill Slep 704-524-7519. Slep Electronics Company, Highway 441, Otto, NC 28763.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.



COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

CONNECTICUT: November 15. SCARA Indoor Ham Radio and Computer Flea Market, N. Haven Park and Recreation Center, 7 Linsley St, N. Haven. Sellers admitted at 7 AM, buyers from 9 AM to 3 PM. Tables are $10 in advance, $15 at the door. General admission $2 per person. Talkin on 146.61 MHz. Reservations for tables must be prepaid by November 4, 1987and no reservation by phone. For information or reservations SASE to: SCARA, POB 81, N. Haven, CT 06473 or call Brad at (203) 265-6478 between 7 PM and 10PM.

ILLINOIS: November. Rockford Hamfest, Forest Hills Lodge, 9900 Forest Hills Rd, Rockford. 8 AM to 4 PM. Tickets $3 advance, $4 at door. Amateur Radio and computer dealers, indoor flea market, outdoor tailgating, radio/computer forums, ARRL speakers, exams, free parking. All on one level. WHEELCHAIR ACCESSIBLE. For advance tickets SASE to Rockford Hamfest, 6514 Swansdown drive, Rockford, IL 61111. For booth/table reservations SASE to Roger Sawvell, KD9MQ, 6514 Swansdown Drive, Rockford, IL 61111 or call (815) 282-1283.

NORTH CAROLINA: November 21 and 22. The 7th annual Greensboro Hamfest Franklin Blvd. National Guard Armory Sponsored by the MARK IV Radio Club. 9 AM to 5 PM. Tickets $4 advance, $5 at gate. New tailgate area. Ticket plus $2 per space. Walk in FCC exams. Information/registration: Fred Redmon, N4GGD, 3109 Goodall Drive, Greensboro, NC 27407 (919) 852-9244 from 0100Z to 0300Z. Tickets only: Henry Hughes, KA4LPA, 2811 Gwaltney Rd, Greensboro, NC 27407. FCC exams: Hugh Brunson, AE4N (919) 852-1087.

ALABAMA: November 14 and 15. The Montgomery ARC's 10th annual Central Alabama Montgomery Hamfest, Ed Teague Arena, Central Alabama State Fairgrounds near Coliseum. Free admission, free parking. Overnight RV parking with hookups $5/night. Flea market and dealer setups Friday 7 to 10 PM Saturday and Sunday 6 AM. Tables $5 each/day or $7 each/both days. No reservations needed. Doors open to public 9 to 4 PM. FCC license exams both days starting 9 AM. For information: Montgomery Hamfest, POB 3141, Montgomery, AL 36109 or call Randy (205) 832-4598 or Ken (205) 271-0028.

COLORADO: November 29. The Denver Radio Club's annual Hamfest and ARRL State Convention, Jefferson County Fairgrounds, 6th Avenue and Indiana, Golden. 9 AM to 2 PM. Swap tables, seminars, code contests. Non-ham events. Admission $2. Tables $5. Talk in on 147.93/33 and 146.52. Contact Dean Haworth, AC0S (303) 279-4956 for more information.

FLORIDA: November 21 and 22. South Florida ARRL Suncoast Convention sponsored by the Florida Gulb Coast ARC Council, St. Petersburg Hilton and Towers. Hugh flea market. Amateur exams. Saturday QCWA luncheon. Tech talks and demos. Registration tickets $4 to November 13. $5/door. For convention information write FGCARC, 1556 - 56thAvenue North, St. Petersburg, FL 33703.

WISCONSIN: November 14. The Milwaukee Repeater Club is sponsoring the third annual "6.91 Friendly Fest". Serb Hall, 51st and Oklahoma Avenue. 8 Am to 1 PM. Sellers 7 AM. All on ground floor with easy access. Rain or shine. On site Amateur exams. Tickets $3. 4' tables $4. Save $1 per ticket or table - SASE with payment to Milwaukee Repeater Club, POB 2123, Milwaukee, WI 53201 by November 7, 1987. Talk in on 146.91 and 146.52.

MASSACHUSETTS: November 21. The Honeywell Bull 1200 Radio Club and the Waltham Amateur Radio Association will hold their annual Amateur Radio and Electronics Auction, Honeywell Bull plant, 300 Concord Road, Billenca. Snack bar and bargain parts store. Doors open 10 AM. Free admission and parking. Talk in on 147.72/12 and 146.04/64 repeaters. For information: Doug Purdy, N1BUB, 3 Visco Road, Burlington, MA 01803.

GEORGIA: October 31 and November 1. Ham Radio & Computer EXPO '87 sponsored by the Alford Memorial Radio Club. Gwinnett County Fairgrounds, Lawrenceville, 20 minutes NE of Atlanta. VEC exams both days, covered flea market, free parking, RV sites with hookups, convenient lodging. $5 admission includes Saturday night cookout. For more information: EXPO '87, POB 1282, Stone Mountain, GA 30086.

MINNESOTA: December 5. The annual Handi-Ham Winter Hamfest, Eagles Club, Faribault. Registration starts 9 AM. Handi-Ham equipment auction. Dinner at noon. Program follows. License exams. Talk in on 19/79. For information: Don Franz, W0FIT, 1114 Frank Avenue, Albert Lea, MN 56007.

OHIO: November 22. The Massillon ARC will sponsor AUCTIONFEST '87. Massillon K of C Hall, off Rt 21. 8 AM to 5 PM. Sellers setup 7 AM. Admission $3.50 advance and $4/door. Tables available $7/8' space. Refreshments available. Free parking. Auction starts 11 AM. Talk in on W8NP, 147.78/.18. For advance registration and information SASE to MARC, POB 73, Massillon, Ohio 44646.

OPERATING EVENTS

"Things to do . . ."

November 8: Armored Forces Amateur Radio Net will commemorate Veteran's Day 0600Z thru Wed Nov 11 2400Z. 80, 40, 20, 15m. For certificate send large SASE to WB1DWR, 16 Berkely Circle, Newington, CT 06111.

November 8: To observe Veteran's Week, members of the Hamfester Radio Club, Chicago, will operate from the Hines VA Hospital's Robert K. "Pappy" Wade, K9CDH, Memorial Ham Shack using Hine's club call K9WFN, 1500Z to 0300Z 40, 20, 2m FM and 2m USB. For a commemorative certificate, send QSL, QSO number and 9x12 SASE with 39 cents postage or $1.00 to Hamfesters Radio Club, Inc., Chicago, c/o Robert K. "Pappy" Wade Memorial Ham Shack, Bld 8, Hines VA Hospital, Hines, IL 60141.

November 25: Cocos - Keeling Island. Listen for Hans, F6GVD and Victor, G3AAG. For two weeks. No specific frequency or time except first 10 minutes of the hour they will stand by for QRP stations only and at half hour for handicapped operators. QSL via QSL manager VK9YC or direct to F6GVD.

HAM EXAMS: The MIT UFH Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday November 18, 7 PM, MIT Room 1-150, 77 Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 646-1641. Exam fee $4.25. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

✓ 185

ELMER'S NOTEBOOK

Tom McMullen, W1SL

receiver buzzwords

Because this is the annual receiver issue, I'll try to clarify some receiver-related terms you might be wondering about. Who knows? This information might even help you choose a rig from among the many available.

One of the biggest problems an Amateur faces is interference from other signals, so I'll emphasize techniques that help reduce that problem.

RIT stands for Receiver Incremental Tuning, a way of tuning the receiver without disturbing the transmitter frequency. This feature is useful if the station you're listening to drifts slightly, or if you have to tune just a wee bit off frequency to minimize the effects of interference. In the earlier days of single-VFO transceivers without RIT, when you moved your receiver dial you also moved your transmitter. The other station then had to move to tune you in. Then you'd move again — and so on. This led to the two stations "walking" each other across the band; if they weren't careful, they could wind up out of bounds. With RIT, you can leave the transmitter alone and move the receiver a few Hz to keep the other station tuned in.

A **direct conversion** or **single conversion** receiver is perhaps the simplest type of heterodyne receiver in use. It's basically a local oscillator (usually a very stable VFO) and a balanced mixer. The rf signal and the VFO are both fed into the mixer, and when the two frequencies are the same (zero-beat with each other), any audio present on the rf signal becomes a product of the mixing process. This audio is fed to audio amplifiers to drive a headset or a speaker, as needed. An rf amplifier is often used ahead of the mixer, and an audio filter after the mixer to prevent hearing the beat notes produced by nearby signals. Many low-power or portable stations use this type of receiver because of its simplicity, light weight, and low power requirements. While **direct conversion** isn't directly related to interference problems, it's worth knowing about this type of receiver in order to understand other discussions to come.

If a single-conversion receiver converts once — from rf to audio frequencies — then it follows that a double-conversion receiver converts twice. The first conversion mixes an rf signal with the first local oscillator, which produces an intermediate frequency signal, abbreviated *i-f*. (Notice the hyphen; it's there so you'll know not to read "i-f" as the word "if.")

The second conversion mixes the i-f signal with a second local oscillator to produce . . . Uh, here's where our nice, neat scheme falls apart!

Older receivers, designed to handle amplitude modulation (a-m), used a diode detector at the end of the i-f amplifier circuit. The second local oscillator would produce another i-f signal, which would then be detected by a diode, to produce audio, etc. In this case, it's a double-conversion receiver. However, newer receivers, designed to handle single-sideband (SSB) signals, needed a different arrangement. Diode detectors are practically useless for SSB detection, so a circuit called a **product detector**, amazingly similar to the single-conversion scheme I mentioned earlier, was developed. This circuit includes a local oscillator that mixes with the i-f signal to produce audio output. The product detector works well with a-m and CW, and really shines with SSB signals.

So whether a receiver is double or triple conversion really depends on the definition of the detector circuit. For example, a receiver that uses a VFO to produce an i-f of, say, 9 MHz, and then a second oscillator and mixer to produce a lower i-f at, perhaps, 455 kHz, which is followed by a diode detector, is clearly a double-conversion receiver.

Does changing the diode detector to a product detector make the receiver **triple conversion**, then? The purists will say yes, but many manufacturers just don't mention it. (And it really isn't important unless you need to know the definition in order to prove a point!)

Double-conversion receivers are important, however, in solving **image problems**. To follow me through this one, **image rejection**, you'll need to look at **fig. 1** and check the arithmetic.

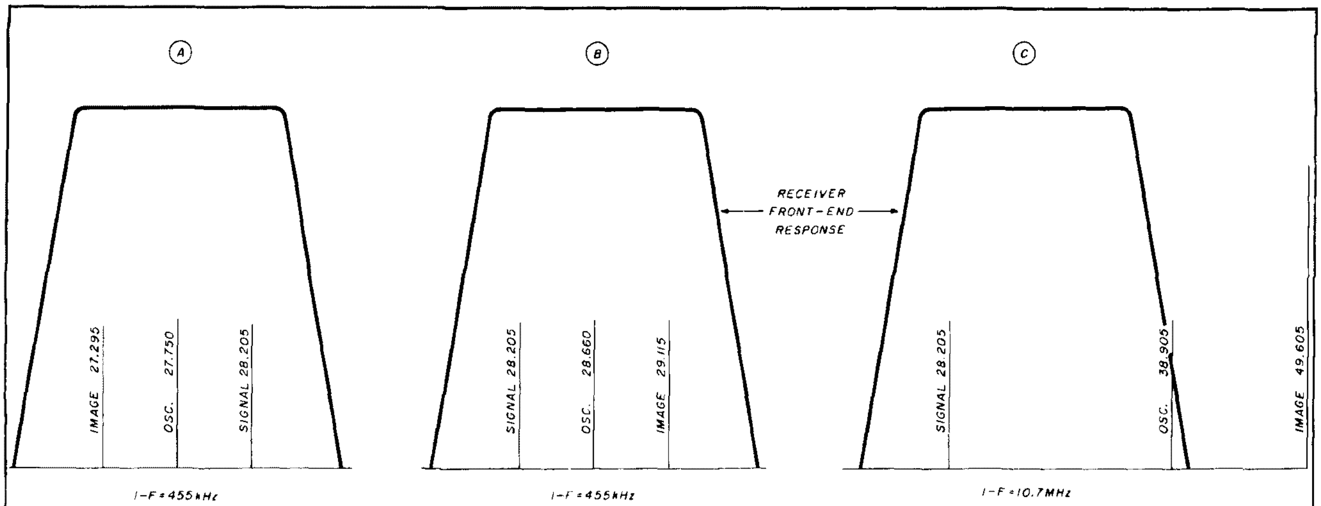


fig. 1. Image rejection is often poor in receivers with a low-frequency i-f, as at A. When the first i-f is high, the image moves away from the receiver front-end response, shown at C.

If the signal you wanted to listen to was the only one on the band, life would be simpler. But there are plenty of signals out there, and most of them aren't the ones you want to hear. A simple receiver (such as a single-conversion type) is capable of receiving all sorts of things you don't want, many of them signals that aren't in the Amateur bands. Let's say you want to tune in a signal at 28.205 MHz. Your i-f is 455 kHz, so your VFO is at 27.750. This produces the right i-f, but if there's a loud signal at 27.295 (as there often is), it too can mix with the VFO to produce 455 kHz.

This intruder is called the **image signal**. An interesting thing is that the image signal is always twice the first i-f away from the signal you want. In the case above, 2 x 455 = 910, and 28.205 − 0.910 = 27.295. If you know that, you can track down suspected image interference.

How do you get rid of it? There are a couple of common tricks: one is to place the VFO above the signal — at 28.660 to receive 28.205 MHz, for example. This would place the image at 29.115, which means that the signal would be from an Amateur station — but that's not much help if it buries your QSO.

A more practical method is to use a double-conversion receiver and make the first i-f high — perhaps 9, 10.7, or even 70 MHz. The high i-f places the image quite some distance away from where the receiver front end is tuned, and it's easier for simple tuned circuits to reject a signal that's far removed from its design frequency. For instance, a 10.7-MHz i-f will place the image of 28.205 at 49.605 MHz, as shown in **fig. 1**. Even a mediocre front end can reject that one.

Another common cure is to build filters (special tuned circuits) that pass only a narrow range of frequencies, say from approximately 27 to 31 MHz for the 10-meter band, but greatly attenuate anything outside that range. Many modern solid-state receivers use this technique on all bands, along with broadband rf amplifier sections, to provide good performance and require minimum attention from the operator.

SINAD isn't a remedy for sinus trouble; it's a test commonly used to determine how well a receiver hears a weak signal. SINAD is an acronym for *signal + noise + distortion* to *noise + distortion* ratio. (Aren't you glad they shortened it?) This is what it means:

If you disconnect the antenna from your receiver and turn the audio gain up, you'll hear a hiss or rushing noise. That's the "noise" part of the formula. It takes a certain amount of signal strength to be heard through that noise. The level of that signal is the "signal" part of the formula. The "distortion" part comes in because a signal can be loud but not clear.

The signal generator used for this test is modulated, and the recovered audio from the receiver is compared with the modulation waveform to see if it has been distorted — and usually, it has. Thus, the test will determine how strong a signal it takes to produce some specific output above the noise, and how badly the i-f filters, audio amplifiers, and even the power supply hum have distorted the audio output.

Fortunately for us, the test results are neatly summed up on a meter on the test equipment, and we don't have to spend a lot of time calculating ratios and such. The test instrument, naturally enough, is called a SINAD meter.

The usual method of rating a receiver under this test is to state a signal strength that's required to meet a particular dB SINAD ratio: for example, 0.5 μV for 12-dB SINAD. The lower the microvolt (μV) number, the better the receiver, and 12 dB is an industry-wide benchmark used in the test.

An i-f notch filter (or i-f notch tuning) is another device used to

reduce the effect of interference. It consists of a high-Q circuit that works within the "window" or passband of the i-f amplifier. Instead of acting as a bandpass device, however, it's a band-stop circuit designed to attenuate greatly whatever frequency it's adjusted for. This is most useful if you're listening to a weak signal (or even a moderately strong one) and someone pops up close enough to create an ear-splitting whistle or lots of "splatter" on top of the signal you want to hear. By adjusting the i-f notch, you can often reduce the commotion to a level you can live with.

An i-f notch filter will have limited usefulness, however, because any notch deep enough to really eliminate an interfering signal will also reduce the strength of the signal you want to hear.

Interference suppression can also be handled by an **audio filter** that cuts off all audio tones outside a narrow range. This is great for CW signals, but voice (SSB) tends to sound hollow and distorted if the audio passband gets too narrow. There is an equivalent to the i-f notch filter called the **audio-notch filter** or **audio-rejection filter**. A piece of electronic trickery that uses op amps to create a phase shift that will cancel the offending tone, it works quite well, and usually consists of one or two integrated circuits, a potentiometer or two, and a few resistors and capacitors. Both the frequency of rejection and the degree of rejection (depth of the notch) are adjustable. The audio-notch filter is a great add-on for direct-conversion receivers.

Another neat bit of electronic sleight-of-hand is **i-f shift**. It takes some of study to figure out how it works, but it's really quite simple. In essence, it works this way: when a signal is in the same i-f passband as the one you want to hear, you just move the passband "window" over a bit until that signal is outside it. You can do the same thing by slowly tuning your receiver until the interference is out of the passband, but when you do that, the signal you want is moving also, and might end up as a tone that's not easy to hear (on CW) or as duck-talk (on SSB).

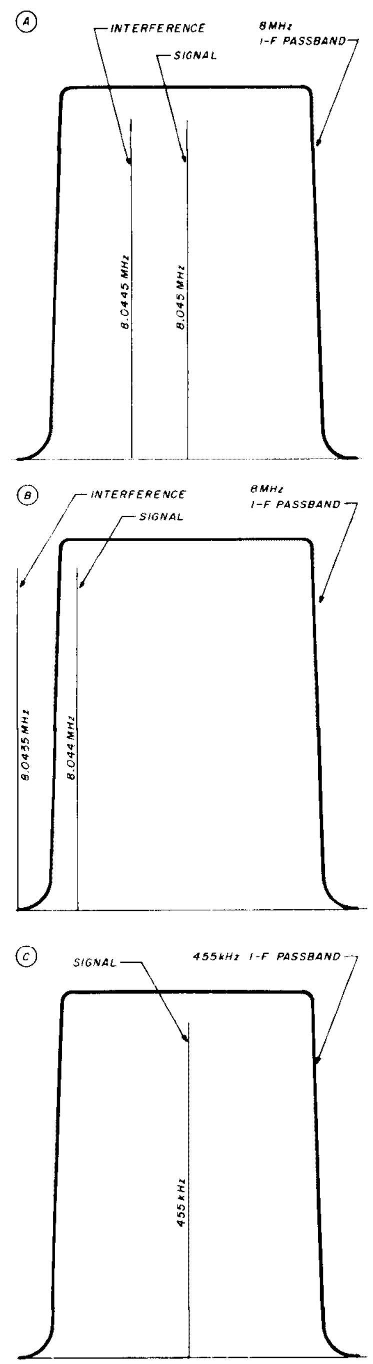


fig. 2. I-F shift, or i-f tuning, can move an interfering signal out of the i-f passband, then place the wanted signal back in the low-freqency i-f window for clear reception. This example uses approximately 8 MHz for a passband filter, then converts down to a conventional 455-kHz i-f for further amplification and detection.

Perhaps **fig. 2** will help clarify this. At **A**, both the interfering signal and the wanted signal are in the i-f passband. By adjusting the i-f shift, you can move the interfering signal out of the passband, as at B, and leave the wanted signal in. Now, the only trick is to get the wanted signal back into the center of the window again, as at **C**.

How do they do that? By adding two more conversions in the i-f amplifier chain, and using the same beat-frequency oscillator (BFO) to mix with the signal twice. For example, you can mix a 455-kHz signal with an 8.0-MHz BFO to produce an 8.455 i-f. This i-f signal then passes through a filter and into another mixer. There, the 8.455-MHz signal mixes with 8.0 to produce the original 455 kHz i-f again.

Now to exercise the cranium a bit more — with the help of **fig. 2** — and get more specific: let's say that the signal you want comes through the i-f amplifiers at 455,000 Hz (455 kHz). The one that's bothering you comes through at 455,500 Hz. This produces the normal result at **A**, with both signals inside the i-f passband. By detuning the 8.500-MHz VFO a few Hz to 8.499, and mixing with the i-f signals, you can change the wanted signal to 8.044, and the interference is at 8.0435 MHz, as shown at **B**.

The 8-MHz i-f filter will pass 8.044, but not 8.0435, so the interference is gone! When 8.044 is again mixed with 8.499, the difference is 455 kHz, which is right back in the middle of your i-f window (at **C**), just where you want it.

Of course, this is a greatly simplified example of how it works, and I've made the frequency separations large to make the example easier to follow, but you get the idea. Many manufacturers use more complex circuits to accomplish this, and some use phase-locked loop (PLL) circuits to move the signals around and reject the unwanted ones. No matter how they do it, the results make it worth looking for this feature in a receiver.

conclusion

The degree of interference rejection you need depends upon the type of operating you do. On most of the hf bands, crowding is a way of life, and the best DX is usually buried beneath several layers of loud signals. It seems to be magic when an experienced operator can peel away those layers to leave an S1 or S2 signal standing alone, perfectly readable among S9+ "locals." By carefully choosing your interference-fighting weapons, and with some practice, you too can become a magician.

Next month, I'll explore the possibilities of 1200 MHz.

ham radio

DECEMBER 1987 / $2.50
Season's Greetings
ham radio magazine
ham radio • December 1987
focus on communications technology
PA0CX

ham radio magazine

DECEMBER 1987

volume 20, number 12

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Europe (via KLM air mail), $37.00; *effective January 1, 1988, $40.00*
Canada, Japan, South Africa and other countries (via surface mail),
one year, $31.00; two years, $55.00; three years, $74.00

All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

international subscription agents: page 119

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio* are available to the blind and physically handicapped from Recorded Periodicals, 919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

contents

hr

REFLECTIONS

Season's Greetings

One afternoon not long ago, Skip and I were discussing the latest video to come to our attention. No, it wasn't the latest flick from our local magnetic media emporium, but rather a professionally produced video entitled "The New World of Amateur Radio" in VHS format.

You're right — it's that 30-minute video from the League that explains what Amateur Radio is all about. I'm sure you're familiar with most of the key players. In fact, in some of the scenes you might even recognize yourself.

It's quite well done, and we enjoyed watching it. I'm not going to go into a scene-by-scene description; instead, I'll just pass on an idea Skip suggested.

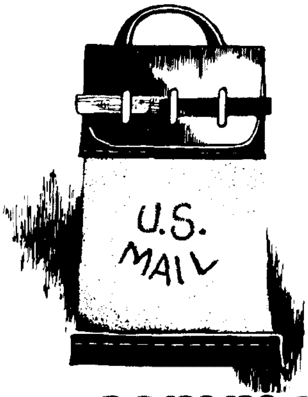
What if quite a few of us each obtained a copy (it costs only $20, and what else can you buy for $20 these days, anyway?) and offered it to our local family video center for free? The ARRL could prepare a poster or other in-store display piece for distribution to hams willing to undertake this effort. I'm pretty sure the family video center that I'm a member of would be willing to at least try it for a while. While there'd be no money exchanged, store owners could offer a free rental of the ARRL tape with the rental of any other. Everybody I know likes a bargain. Used as a promotional item, it's conceivable that the tape might actually help business.

Wait a second. Wasn't this film meant to be distributed to ham clubs, schools, etc.? Absolutely. *But hams clubs already have hams.* Wouldn't it make sense to make the tape available to the general public? Doing this might have several positive effects: first, it might encourage some of our younger generation to find out something about Amateur Radio; second, it can't hurt our image. Maybe one of those people borrowing the tape will just happen to be that neighbor who's been so critical of your tower or your operation. It might explain a few things to him. By jingo, I can see it now — an 80-meter, double-extended zepp strung between your property and his!

A possibility? Contact the American Radio Relay League's Publication Sales Office, Dept. NW/HR, 225 Main Street, Newington, Connecticut 06111, for your copies of "The New World of Amateur Radio" — one for you, one for your neighborhood video store, and five or ten more for all the lucky people on your holiday gift list.

Happy Holidays!

Rich Rosen, K2RR
Editor-in-Chief



comments

sentimental technocrats speak

Dear HR:

The "Reflections" column of September 1987 ("A Sentimental Technocrat Speaks") was the best thing written about Amateur Radio in 20 years. Mr. Zavrel, W7SX, captured my feelings as well as those of most of my friends with his well-written article . . . he forgot one dislike, however: *ready-made coax with crimp-on connectors.*

J. R. Sheller, KN8Z (ex WA8ZDF)

Dear HR:

I loved Bob Zavrel's editorial (September 1987). It's my turn now — but aren't we too young to be talking like this?

What about the warm glow of the tubes, the click of the big antenna relay switching from receive to transmit, the smell of wax capacitors and carbon resistors cooking, the drifting of the old receiver, the steadfastness of that rockbound 6146, the heterodynes of the a-m bands, the quality of the audio on those signals, all those homebrew radios and amplifiers with those weird, unheard-of tubes, the vibrating transmitter cabinet tops, the occasional job of peaking those slug coils in the rf section of the receiver and that "plastic" tuning wand used to do so? How about the old tube tester down at the K&B, the ease of changing tubes, and the reliability of the fact that if a tube wasn't lit, *that* was the problem? (This is why I dislike metal tubes.) And what about the deep red glow of an overloaded 6146, the pop of a high voltage arc, blown fuses, the smell and sting of finger skin *on a hot tube, the smell and heat of* natural convection; the burned spots on painted cabinet tops and the smell of cooking bakelite pc boards? The smell of a new roll of wire, of hot solder flux — and the memory of running home after school to turn the rig on, after you'd been given a 50-foot length of coax . . . the thrill of that first QSO, of wondering who might answer a CQ — and most of all, *old radio friends.*

Richard W. Thimmesch, WA5NYG
Belle Chasse, Louisiana 70037

romantic whining?

Dear HR:

I'd like to take this opportunity to respond to Rich Rosen's editorial, "Evolution" (August 1987).

My experience with readers and kit buyers indicates that he is correct; most avid builders *are* older. Many, having already lost wives and the ability to focus beyond 8 inches, are dying off even as we speak. Others of us simply never recovered from the war, and make little radios for therapeutic reasons.

Nevertheless, acknowledging that fact touches a raw, primal nerve-ending in my Amateur Radio soul. It makes me want to fire up, grab my rusty old J-38, and take a stand. "Don't hide behind that 940, you paper-crazed DX junkie," I'd pound. "Pull your iron, and let's see if you've got what it takes to call yourself a REAL ham!"

But alas, such romantic whining from the island of QRP would only be lost in a turbid sea of mixer-crushing affluence. Perhaps, more constructively, I could simply ask that a quiet spot be reserved for my bones . . . in the ARRL museum.

Rick Littlefield, K1BQT
Barrington, New Hampshire 03825

moon bounce

Dear HR:

While it is correct that "moon bounce" first occurred in 1946 (see W1JR's "VHF/UHF World," August 1987), the radar used was not commercial, but military. The event took place at the United States Army Signal Corps Laboratories at Belmar, New Jersey. *The New York Daily Mirror* of Friday, January 25, 1946 (2 cents a copy!) covered the story of Project Diana under the headline, "Army Contacts The Moon."

ham radio continues to be outstanding. But how could you miss with Mssrs. Reisert, Orr, Beers — and others — all contributing to a single issue?

Len Sheer, W7WRQ
Phoenix, Arizona 85018

UHF/SHF newsletter

Dear HR:

I enjoyed the July issue of *ham radio* very much, and agree completely with WA2LQQ's view on the use of bands from 13 cm "upward" (Vern Riportella, "13 cm: Onwards and Upwards," page 4).

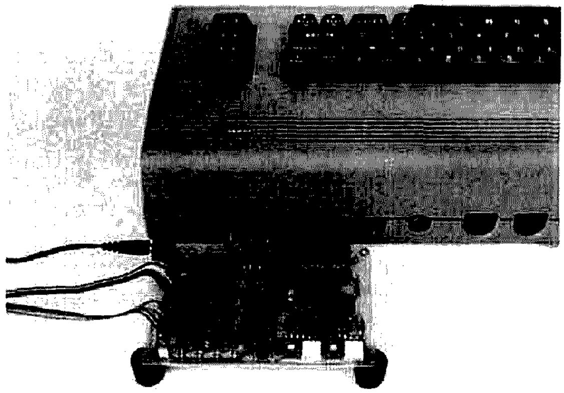
I'm really concerned that publications available in the United States don't hold a candle to some of the European publications in terms of their presentation of UHF/SHF technical material. Take any edition of *Dubus*, for example, and you'll see what I mean.

I'm doing what little I can with *VHF-Plus Update*, and I know you're doing quite a lot with *ham radio*, but there's a long way to go, and I hope that other major Amateur publications will get wise to the importance of our UHF/SHF bands!

Jack C. Parker, KC0W
4016 Narrows Road
Erlanger, Kentucky 41018

Note: Jack publishes a fine newsletter called *KC0W's VHF-Plus Update*. It's well worth subscribing to. — Ed.

Track satellites with
your personal computer



a simple rotor interface board
for the C-64 and the VIC-20

The AUTOTRAK project combines three of my favorite subjects — Amateur Radio, computers, and Amateur satellites.

It began several years ago when I purchased a ZX81 (later to become the Timex 1000) computer, taught myself BASIC, and developed a program for tracking satellites. Shortly afterward, AMSAT chose the ZX81 to be part of its AMS81 project to develop tracking software and a companion hardware board to control rotors for automatic antenna aiming. Though I was privileged to be one of the beta testers of the software, the hardware board never appeared; I assume it couldn't be produced for the "under $100" figure that had been targeted.

Seeing a real need for automatic rotor control, I decided to try to design one to interface to the tracking program I'd developed. It had to be simple, inexpensive, and easy to use. The AUTOTRAK board meets these criteria, and is adaptable to many different rotors and a variety of computers. While the board was sold commercially by Spectrum West and although I still build and market them, I'm pleased to share the design with others.

This article describes its use with the Commodore 64 and VIC-20, but the design can be made to work with any computer that allows you access to the address and data lines. The board will interface with many light-duty rotors that use a linear pot to "sense" antenna direction — for example, the Kenpro 400/500/5400 and HD73. The board output can also be configured to support the new computer-ready Kenpro 5400A/5600A.

Designed to be powered by an 11.0- to 15-volt ac wall transformer, AUTOTRAK won't operate rotors with brakes or those of the chunk-chunk style. Accuracy is within a couple of degrees, which is sufficient for all but very large arrays. Its overall cost should be only about $70.

The software consists of a couple of short program lines, written in BASIC, which you can add to your favorite tracking program. (The new SUPER VR85 tracking program has the coding already built in.) A short operating program and software information are supplied at the end of the article.

theory of operation

Your tracking program will calculate where the satellite is supposed to be at a particular time and provide azimuth and elevation bearings to the satellite for that time. The new program lines you add to your program will calculate a number (between 0 and 255) representing your azimuth and elevation bearings. These numbers are POKEd onto your computer's data bus, where they're latched by D-to-A converters and changed to an analog voltage corresponding to the direction in which the computer says your antennas should be pointing. Meanwhile, the actual direction of each antenna is brought onto the board via the direction "sense" lines from the rotor controllers. After being processed, these voltages, and those of the D-to-A converters, are summed together and applied

By Neil Hill, K7NH, 22104 66th Avenue W., Mountlake Terrace, Washington 98043

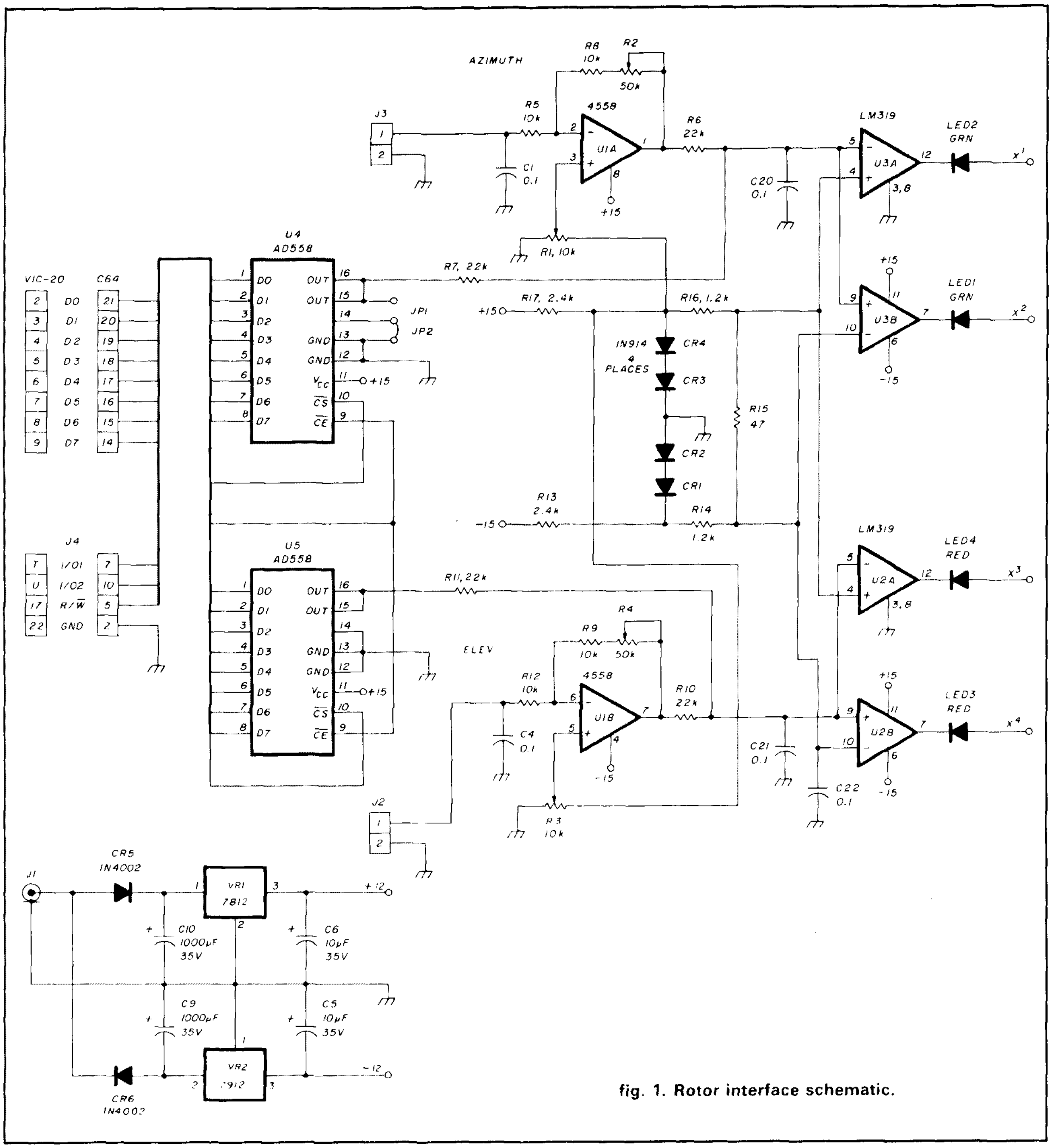


fig. 1. Rotor interface schematic.

to "window" comparators. If the output voltage of the summing circuit is at or near zero, it will fall into the window and the antenna will not move. However, if the voltages are unequal, there will be a voltage and polarity difference and one of the two comparators making up the window comparator will be turned on. Through an appropriate output circuit, the antenna will then be rotated until the output of the summing circuit reaches zero, at which time the comparator will turn off, leaving the antenna pointing where the program says it should.

For details, refer to the schematic (**fig. 1**) and follow along. As noted above, two AD558 D-to-A converters continuously monitor the data lines and will latch and hold whatever data is ready whenever their read and enable lines are low. The AD558 was chosen for three important reasons: it provides a voltage rather than current output; the full-scale voltage can

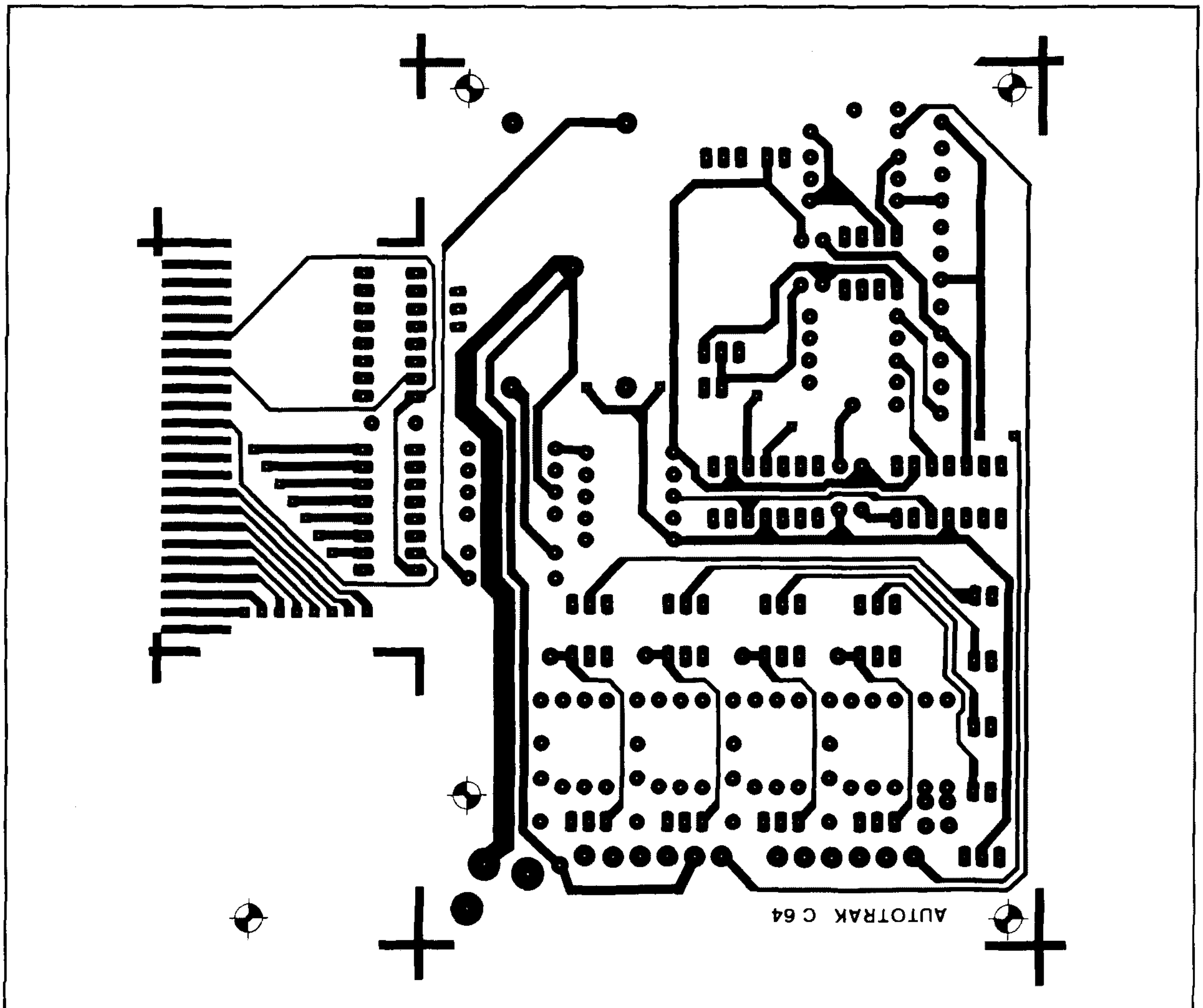


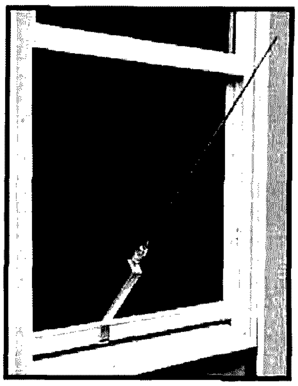
fig. 2A. Full-size board art for C-64 (top).

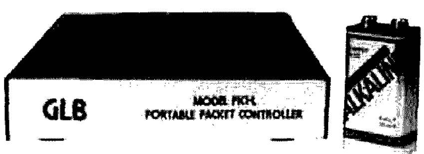
be set for either 2.5 or 9.75 volts; and it has a built-in latch, which allows the computer to go on its way once the chip has received the information it needs.

Part of the simplicity of the AUTOTRAK design is attributable to the presence, on the Commodore 64 and VIC-20, of two 1-K wide I/O sections that aren't normally used. I simply POKE an address in each section to activate the azimuth and elevation D-to-A converters momentarily. (On other brands of computers, you'll probably need to decode the address lines, but this should require only a couple of ICs.) The output of each D-to-A converter is applied to one side of a summing circuit consisting of two 22-k resistors. The other side of each summing circuit is fed by the output of one half of an LM4558 op amp, which accepts the sense voltage from the associated rotor, inverts it, and "matches" it to the voltage range of the corresponding D-to-A converter.

Adjustment of the + input of the op amp sets the low or CCW end of rotation, and its gain adjustment sets the high or CW end. The outputs of the summing circuits are tied to window comparators, each formed by both halves of an LM319. The high speed of the LM319 is important for accuracy, but it's very sensitive to noise and ac signals on its inputs, so special care must be taken to control the input signals. The size of the window determines the accuracy of the board. I found a 47-ohm resistor to be about the right value. Increasing this value widens the window, and decreasing it causes it to close; however, too small a value causes both halves of the comparator to be on at the same time, which can cause problems.

The outputs of these comparators in turn operate a pair of optoisolators, one for each rotor direction, and LEDs that indicate which direction is active. These LEDs are also used when making the setup adjust-





parts list

C1-4,7,8,11*,13*, 15*,17*,19-22	0.1 μF, 50 volts, 0.2-inch CTC
C5,6	10 μF, 35-volt electrolytic
C9,10	1000 μF, 35-volt electrolytic
C12*,14*,16*,18*	0.01 μF, 500-volt disc
D5,6	1N4002 200-volt PIN diode
D1-4	1N914 diode
J1	Power connector
R1,3	10-k pot, 1/2-inch square, 1 turn (Bourns 3386W, 103K)
R2,4	50-k pot, 1/2-inch square, 1 turn (Bourns 3386W, 503K)
R5,8,9,12	10-k, 1/4-watt
R6,7,10,11	22-k, 1/4-watt
R13,17	1.2-k, 1/4-watt
R14,16,21,24,27,30	2.4-k, 1/4-watt
R15	68 ohms, 1/4-watt
R18,19	680 ohms, 1/4-watt
R20*,23*,26*,29*	180 ohms, 1/4-watt
R22*,25*,28*,31*	39 ohms, 1/4-watt
SW1	DPST (miniature)
U1	RC4558 dual op amp
U2,3	LM319 dual comparator
U4,5	AD558 D-to-A convertor (available from Analog Devices, Route 1, Industrial Park, Box 280, Norwood, MA 02062)
U6*,7*,8*,9*	MOC3011 optoisolator
U10*,11*,12*,13*	TIC226B triac
VR1	7812 voltage regulator (+12)
VR2	7912 voltage regulator (−12)
Green LED	TIL222
Red LED	TIL220
Cable	10-conductor multicolored (5 feet)
Transformer	11.0- to 15-volt ac, wall mounted
Autotrak pc board	Available from NH Enterprises, 22104 66th Avenue West, Mountlake Terrace, Washington 98043

Parts needed for computer-ready controllers: U6-9, Optoisolators (TIL113); 4 2N7000 FETlingtons.

(*) designates parts to be omitted in computer-ready controller.

ments. The actual circuit used to interface to your rotor system depends on what kind of rotor you use. Most small rotors use ac motors, so an optoisolator triac driver such as an MOC 3011 and triacs are used. This acts as a remote ac switch for the rotator motor. However, by using TIL113 optoisolators and 2N7000 FETlingtons (in which FETs are substituted for a Darlington transistor pair) the board acts like a low-power on/off switch to ground so that computer-ready rotors can be controlled. If you need more voltage or current to be controlled, just substitute power MOSFETS such as the IRF 520 series for the FETlingtons.

Voltage for the board is provided by a simple dual-voltage (+15 and −15)-volt supply using inexpensive regulators and powered by a small 11.0- to 15-volt ac transformer that plugs into a wall outlet.* A switch is employed to disconnect voltage to the optoisolators, thus disabling the board when manual control of the rotor controllers is desired.

ESD caution

As in all such projects, it's important to minimize the possibility of electrostatic discharge (ESD) damage to components. The AD558 D-to-A converters are quite expensive, and also sensitive to ESD damage, so take the appropriate precautions. (One friend covers his work area with aluminum foil before starting a project.) When handling the AUTOTRAK board, try not to touch the end that plugs into the computer; the "fingers" go directly to the AD558s.

* ± NS 12 volt regulators and a 12-volt ac transformer may be substituted if more readily available.

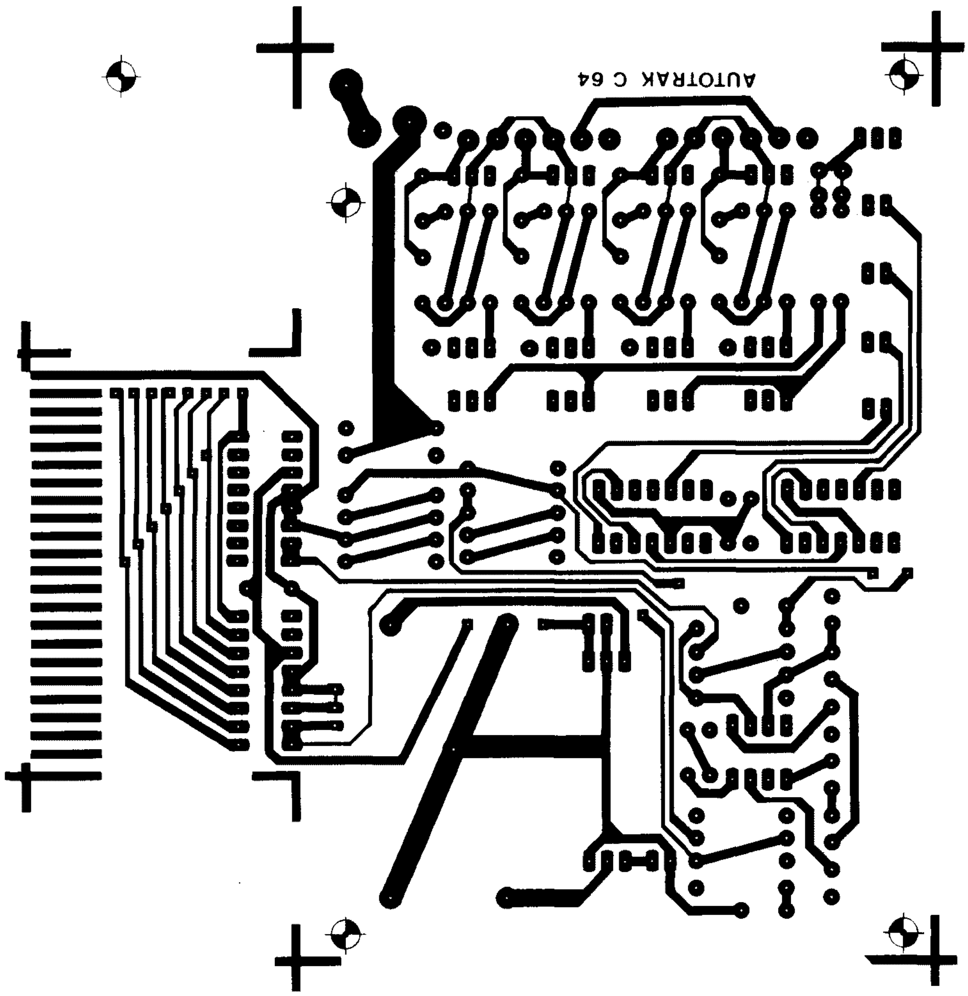


fig. 2B. Full-size board art for C-64 (bottom).

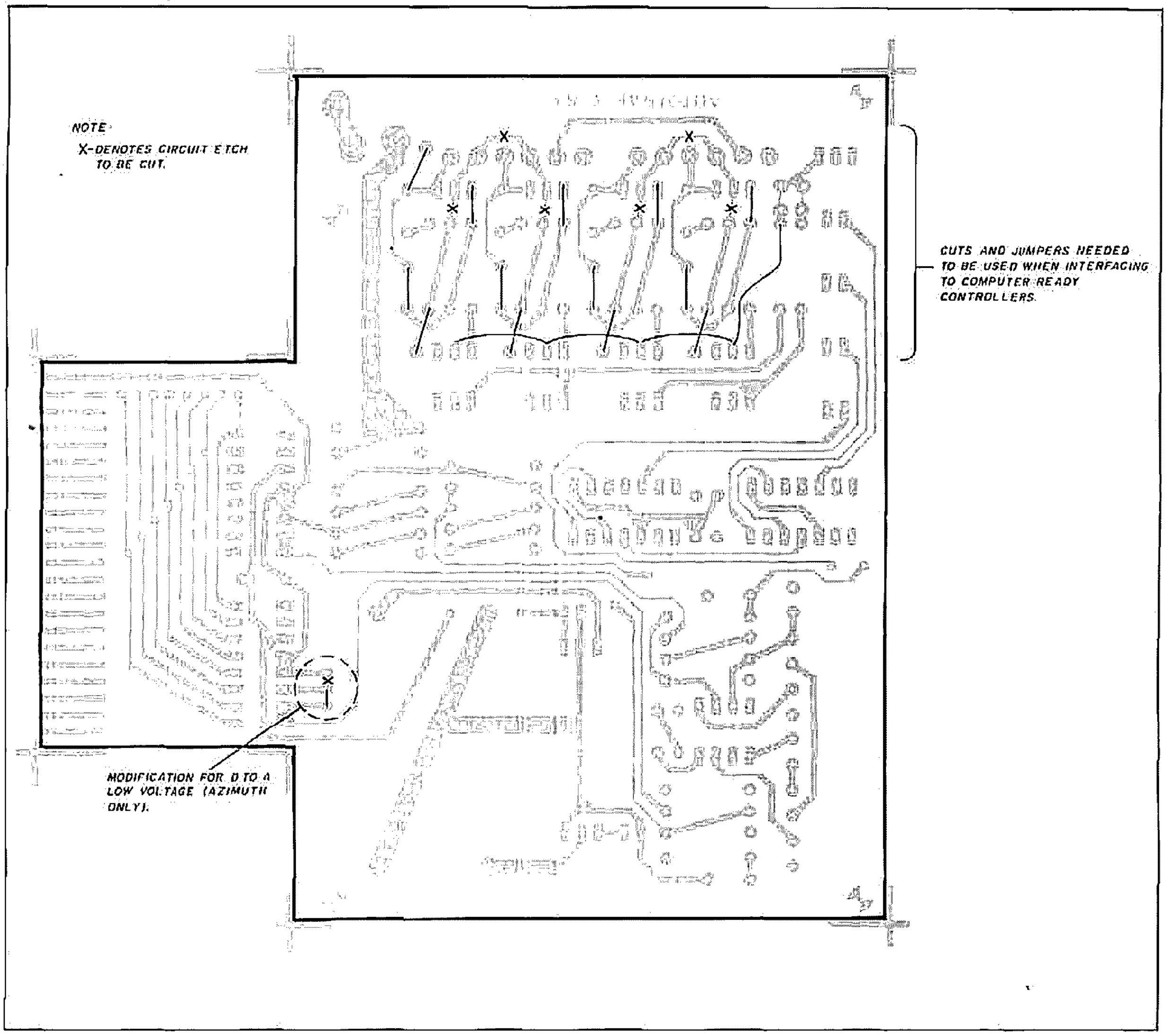
building the board

Assembling the board is straightforward. The C-64 and VIC-20 AUTOTRAK boards are identical except for the computer connector. For those of you who are making your own boards from the supplied artwork (see **figs. 2** and **3**), there are two things to remember: first, unless your boards have through-hole plating, you must supply the through hole connections with a wire placed in the through holes and soldered on both sides; and second, any trace to component connections on the top of the board must be soldered on top of the board rather than on the bottom.

I use the "layer" method when assembling the boards. First I insert the shortest parts, normally the resistors and diodes, and cover them with something flat and stiff (like a piece of corrugated cardboard). Holding this "sandwich" together, I turn the board upside down, leaving the component legs sticking up, ready for soldering. After soldering, I clip the leads and move on, inserting the next tallest group of parts such as ICs, small capacitors, and variable pots. The switch, LEDs, filter capacitors, and the input power connector are mounted last. For parts placement and orientation, see **fig. 4**.

Note that the voltage regulators are installed upside down (metal side up) in order to conserve board space. After mounting the variable pots, turn them to the center of their range to prevent confusion later, during testing. When installing the electrolytic capacitors, make sure their polarity is correct.

All components are mounted on the top of the board except C20-C22. Keep the leads on these capacitors short because they're used to shunt to ground any noise or ac voltage, which might confuse the operation of the comparators. Each of the four LEDs



should be mounted with its flat spot towards the edge of the board. If there's no flat spot, note the length of the mounting leads and mount the shorter one towards the edge. *No cuts or jumpers are necessary when assembling the standard ac motor version of the board.*

Differences for the computer-ready version concern only the output circuitry (**fig. 5**). Everything else stays the same. See **fig. 5(B)** for parts changes and **fig. 2C** for the six cuts and various jumpers needed. All cuts are made on the bottom side of the board and are easily accomplished with an X-acto™ knife or equivalent. Jumpers can be mounted from the top or bottom side of the board, but should not be run over an exposed trace unless they're insulated. Don't forget the +15 volt lead to pin 5 of each of the TIL113s, and watch the lead placement of the 2N7000s. (See **fig. 4(B)**.)

After the board is completely assembled, give it a careful visual inspection, especially for solder shorts. Are the part values correct? Are the solder connections smooth and shiny? Did you miss any? Is the polarity correct on the electrolytic capacitors and diodes? Are the LEDs mounted with their flat sides toward the edge of the board, and the voltage regulators upside down and bent over? How about the three 0.1-μF capacitors mounted across the pins of the LM319s on the bottom side of the board; did you forget them? All correct? Great — let's move on.

preliminary testing

Be sure to test your work *before* you plug the AUTOTRAK board into your computer and before running any wires to your rotors. First verify that the four variable pots are somewhere in the middle of their ranges. Next turn on the enable switch (with the handle toward the top edge of the board) and connect

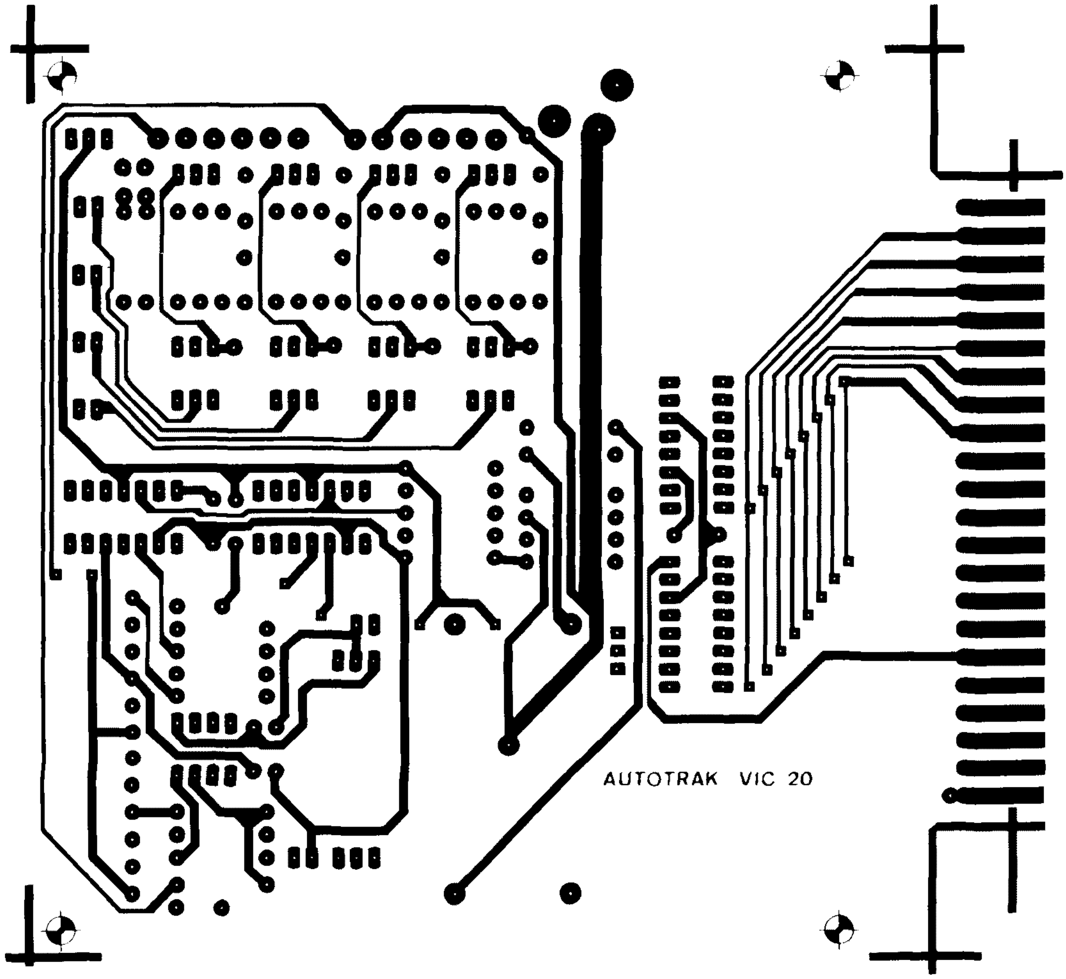


fig. 3A. Full-size board art for VIC-20 (top).

the 15-volt ac input power to the ac power connector (J1). Make sure one of each color LED is lit. If they're not, remove the ac power and recheck the parts, their orientation, and their solder connections before proceeding. If everything looks all right, reconnect the ac and check the output of the regulators for + and − 15 volts.

If the voltage is correct but the LEDs still don't operate correctly, check to confirm that either pin 7 or 12 of the LM319s is near 14 volts. If neither is, check the polarity of the LEDs. If both pins are near 14 volts, look for trouble in the LM319 circuitry. When the LEDs operate correctly, you're ready to proceed. The operation of the D to A converters, op amps and triacs will be checked later.

To complete the board, connect the 10-wire (or 8-wire for the computer-ready version) multicolored rotor interconnect cable and mount two 5/8-inch rubber feet (or equivalent) to the rear holes of the board for support.

rotor preparation

Unless your rotors are the new computer-ready type, you may need to make a small modification to allow access to both sides of the direction switches. Note **figs. 6** and **7**, then consult the schematic in your rotor manual and identify the following: the line from the rotor head to the controller used for sensing direction, the ground return for the sensing line, and the direction switch lines.

Identify the ac common wire from the transformer to the rotor direction switches; if it isn't brought out to a terminal, the controller wiring must be modified to allow access (see **fig. 7**). Wire it to an unused terminal at the rear of your controller if one is available, or supply one to which it can be attached. An alter-

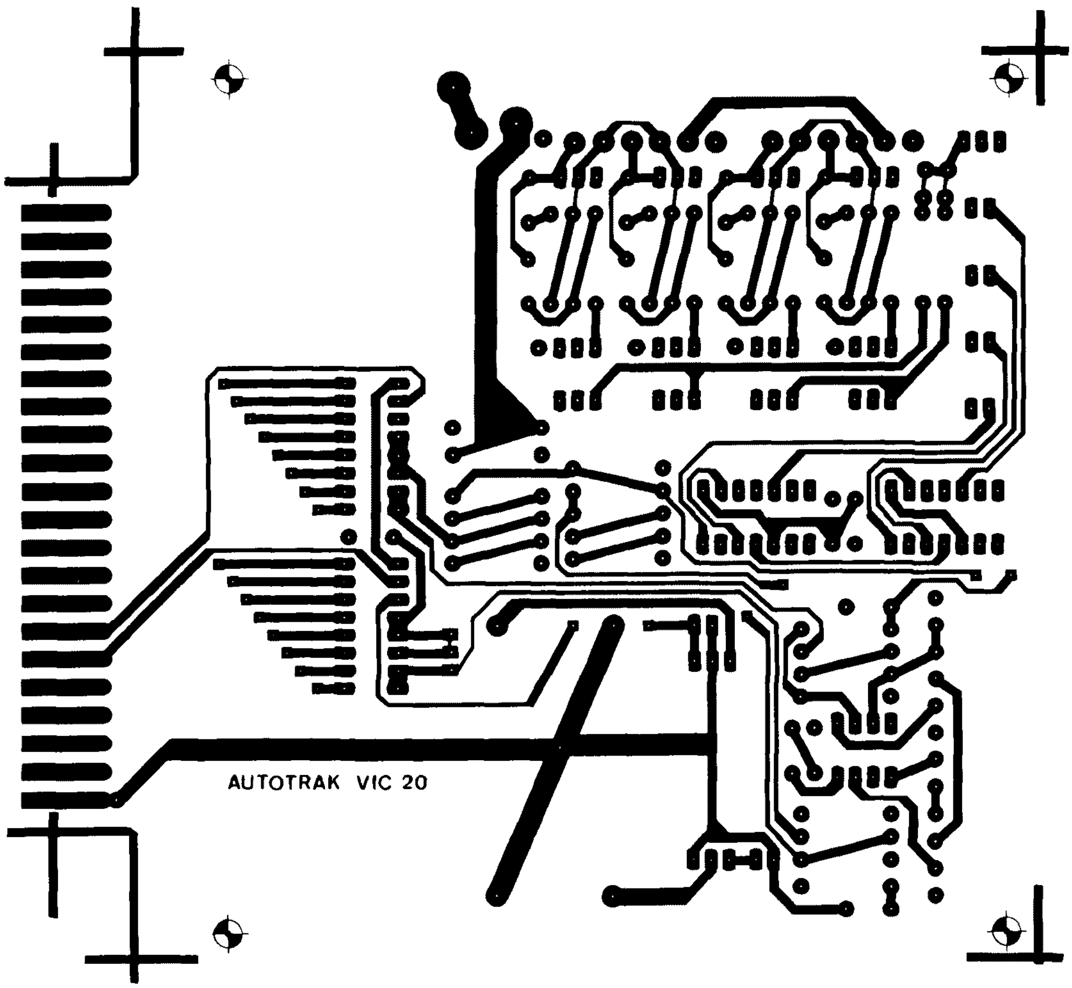


fig. 3B. Full-size board art for VIC-20 (bottom).

native would be to wire in a multiwire "pigtail" to your controller with a connector so that the AUTOTRAK wires can be disconnected.

You'll also need to check the voltage of your rotor's sense lines. The AUTOTRAK board can work with sensing lines between 0.5 and 9.5 volts. If the voltage is higher, a simple voltage divider (see **fig. 8**) can be built into the board to bring it to about 8 volts. If the voltage is less than 2 volts, remove the short across JP1 (see **fig. 1** for location) with an X-acto® knife and install JP2, using a small piece of wire. This changes the maximum output of the D-to-A converter to approximately 2.5 volts, where your low-sensing voltage can be more easily matched.

calibration

Calibration should be done one rotor at a time, starting with bearing. Turn your computer off. Then plug the AUTOTRAK unit into the expansion port. Turn your computer on, connect the ac to the board, and turn on the enable switch. On the rotor controller, locate the direction-sensing voltage terminal and its ground return line (or the equivalant pins on a computer-ready rotor) and connect the wires from J3, pins 1 and 2 respectively, to them. Using its controller, move your rotor to its ccw end. Now type in the following POKE command for the C-64: **POKE 56832,0** (for the VIC-20, use **POKE 39936,0**) and press RETURN. Notice the green LEDs; one should be lit. Adjust R1 (the leftmost pot) back and forth. You should find you can light either green LED, with a neutral spot, or window, showing between them when neither is lit. If adjusting R1 causes both LEDs to light, it may be that you have too much noise (or ac ripple) on the sense line from your rotor. Try putting a 10- to 100-μF cap between the sense line and ground (see **fig. 9**).

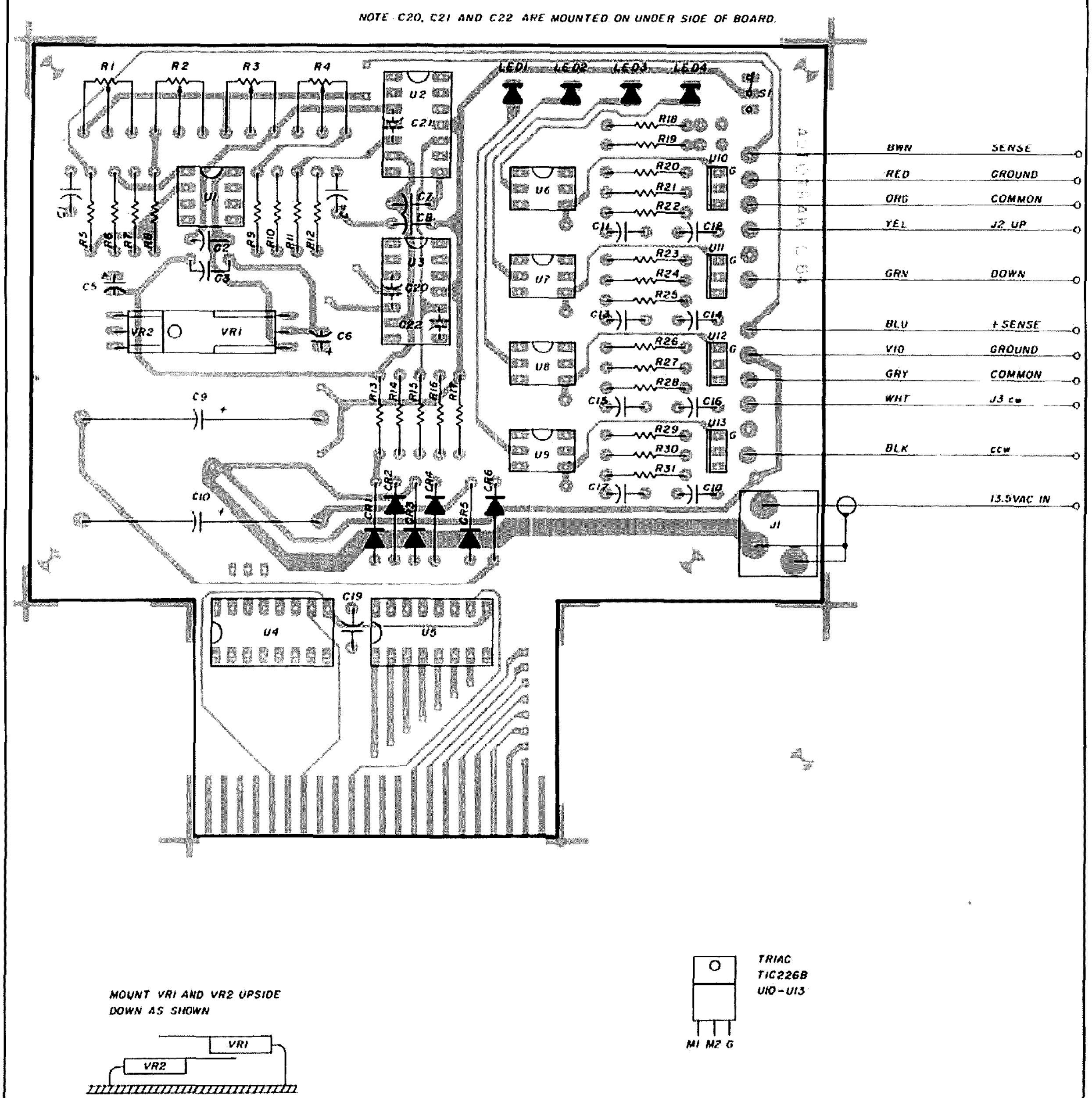


fig. 4A. C-64 parts placement diagram: standard layout.

Adjust R1 to the center of the window. If this can't be done, check for these conditions: U5 (the azimuth D-to-A converter) pin 14 should be at or near zero volts; the input sense line from your rotor should also be near zero volts; correspondingly, U1 (the inverting op amp), pin 1 should be near zero volts or slightly negative and somewhat adjustable by R1. The POKE value mentioned above sets the output of U5 to zero. The ccw end of rotor rotation should be the low-voltage end. R1 sets the op amp to match the output of U5, but with opposite polarity. When these conditions are met, you're ready to proceed. Move the rotor manually to its cw end, enter **POKE 56832,255** (**POKE 39936,255** for the VIC-20) and press RETURN. Again, one green LED should light. This time, adjust R2 (the second pot from the left) to the window where neither LED is on. This adjusts the cw end of rotation. If you can't find a window, check U5 pin 14 for approximately 9.5 volts (the maximum output of the D-to-A converter); U1 pin 1 should be adjustable by R2

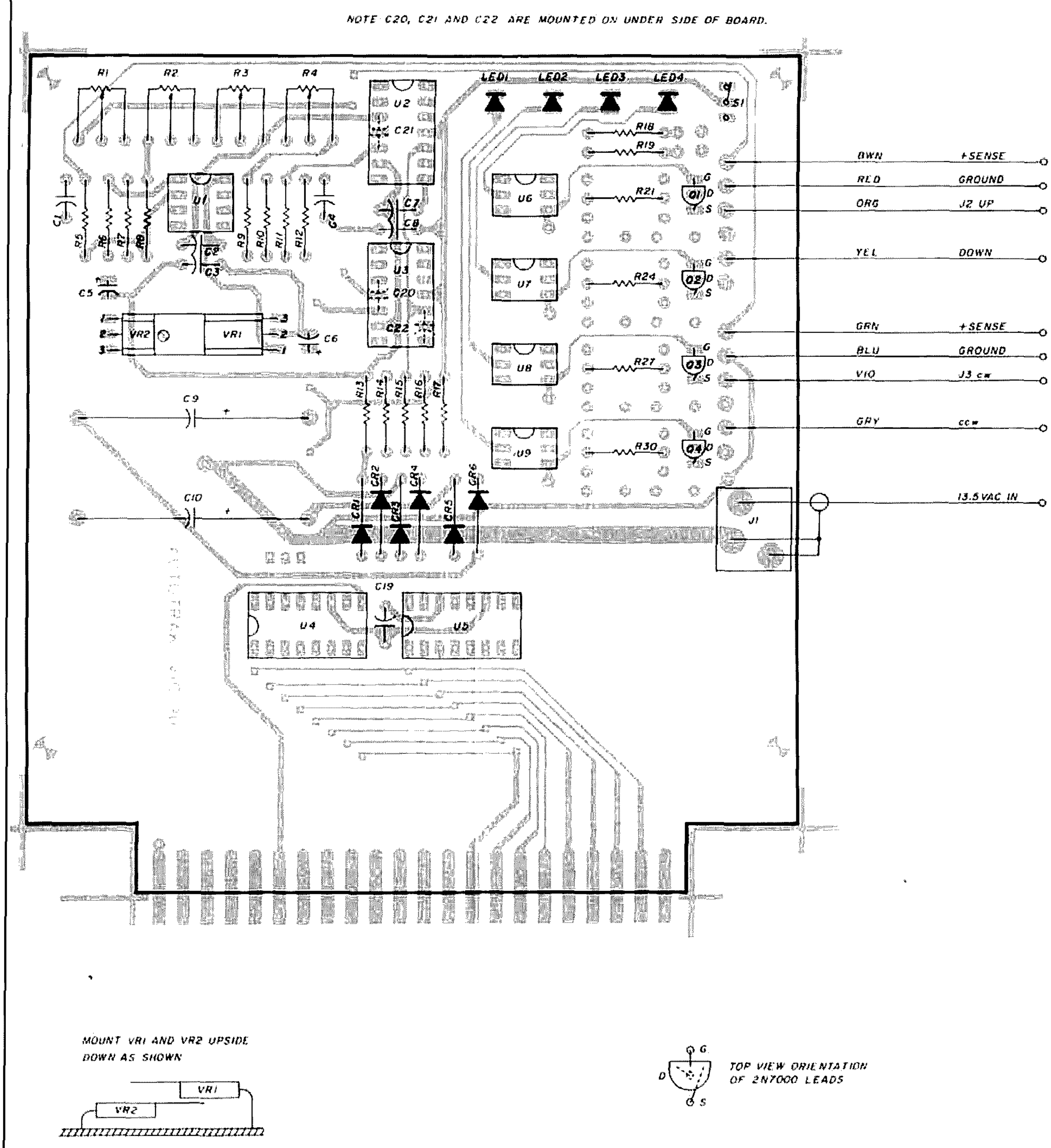


fig. 4B. VIC-20 parts placement diagram: output changes for computer-ready version.

to a negative value matching this voltage. Because there's some interaction between adjustments, it's important to repeat the calibration steps at least twice. You may want to make these adjustments with the rotor positioned several degrees in from the extreme ends to allow some slack for changes due to time and/or temperature.

Now you can connect the wires to the direction switches. Be careful to hook them up correctly and use POKE commands to verify that they rotate in the correct direction. Reverse them if they seem to operate backwards.

To hook up the elevation rotors, use the same procedure as with the azimuth rotor, but connect the

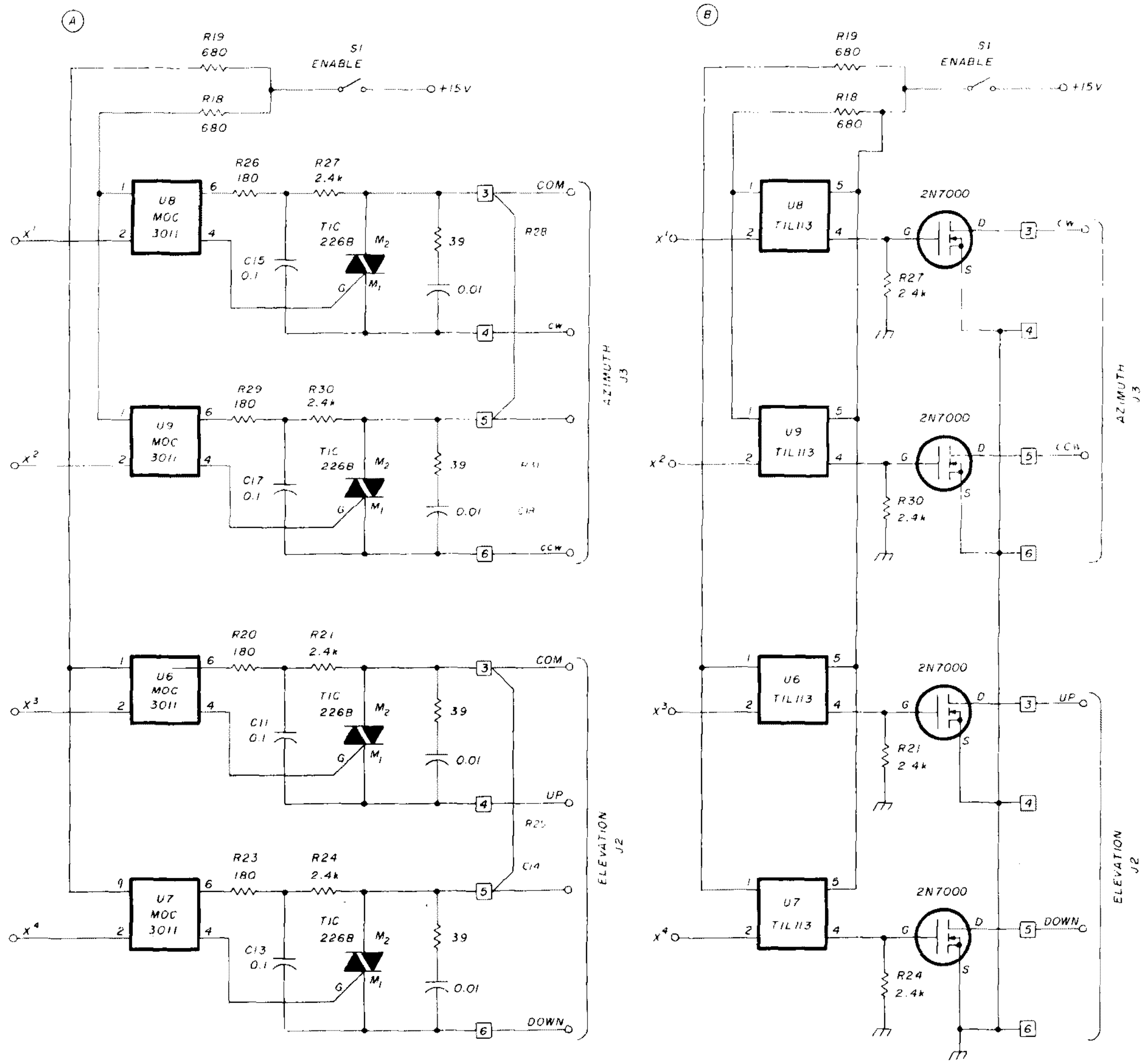


fig. 5. AUTOTRAK output circuit: (A) for ac motors (standard configuration); (B) for computer-ready rotators.

wires to J2 and follow these POKE commands: for down (horizon), use **POKE 57088,0** (**POKE 38912,0** for the VIC-20) and for straight up (90 degrees), use **POKE 57088,127** (**POKE 38912,127** for the VIC-20). Adjust R3 (the second pot from the right) for zero-degree adjustment and R4 (the rightmost pot) for the 90-degree adjustment. Watch the *red* LEDs this time.

quick check

Here's a quick calibration sequence for checking or occasional recalibration.

•**Azimuth:**

POKE 56832,0 (**39936,0** for the VIC-20).

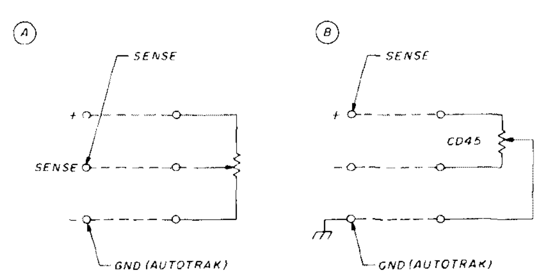


fig. 6. Simple modification allows access to both sides of direction switches.

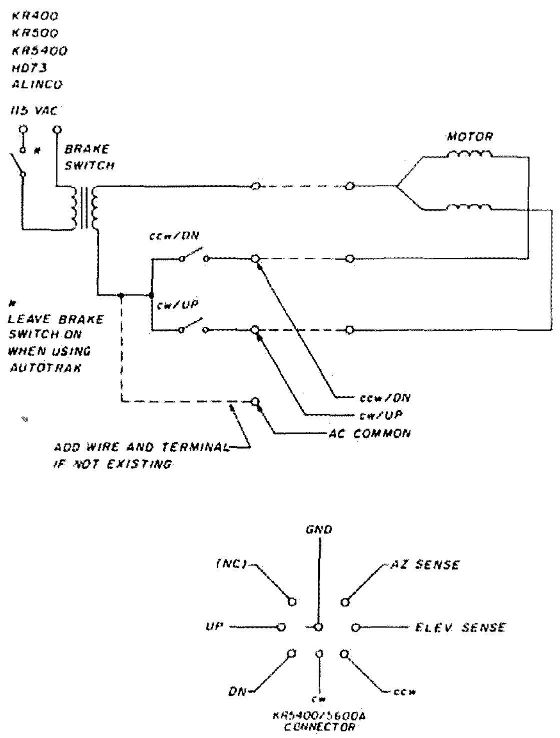


fig. 7. If ac common wire isn't brought out to terminal, modify controller wiring as shown.

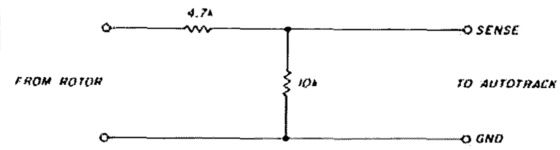


fig. 8. Add simple voltage divider if sense line is more than 9 volts.

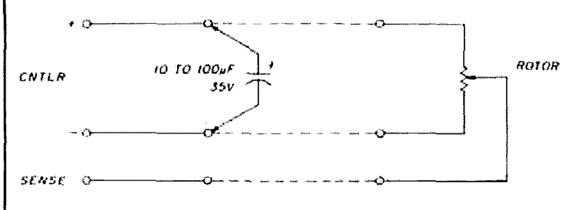


fig. 9. If both LEDs come on at the same time (noise on sense line), add a 10- to 100-µF capacitor across terminals at rotor controller.

Adjust R1 for both green LEDs out with rotor at ccw end.

POKE 56832,255 (39936,255 for the VIC-20).

Adjust R2 for both green LEDs out with rotor at cw end.

•**Elevation:**

POKE 57088,0 (38912,0 for the VIC-20).

Adjust R3 for both red LEDs out with rotor at 0 degrees (horizon).

POKE 57088,127 (38912,127 for the VIC-20).

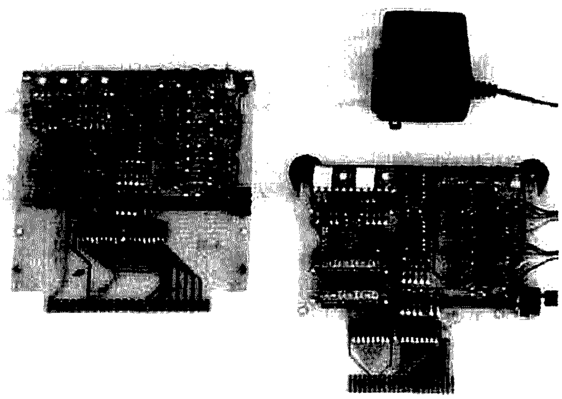


Photo A. Top view, VIC-20 (left) and C-64 (right) **AUTOTRAK** boards. 15-volt wall-mounted transformer is shown at upper right.

```
10 REM MANUAL AUTOTRAK PGM BY NEIL HILL, K7NH
20 PRINT "                 MANUAL AUTOTRAK MODE"
30 PRINT "ENTER AZIMUTH (0 TO 359), PRECEDE WITH B"
40 PRINT "       EXAMPLE: B0, B45, B335"
50 PRINT "  OR ELEVATION (0 TO 90), PRECEDE BY E"
60 PRINT "       EXAMPLE: E0, E45, E87"
70 PRINT
80 INPUT AD$: AD=VAL(MID$(AD$,2)): IF LEFT$(AD$,1)="E" THEN 130
90 IF LEFT$(AD$,1)<>"B" THEN PRINT "PRECEDED BY B OR E? TRY AGAIN": GOTO 80
100 IF AD>=360 THEN PRINT "AZIMUTH 0 TO 359? TRY AGAIN": GOTO 80
110 AB=(180+AD)*.71: IF AB>255 THEN AB=AB-255
120 POKE 56832,AB: PRINT "OK": GOTO 80
130 IF AD>90 THEN PRINT "ELEVATION 0 TO 90?  TRY AGAIN": GOTO 80
140 AE=AD*1.4: POKE 57088,AE: PRINT "OK": GOTO 80
```

fig. 10. Program for manual operation of **AUTOTRAK** using the C-64.

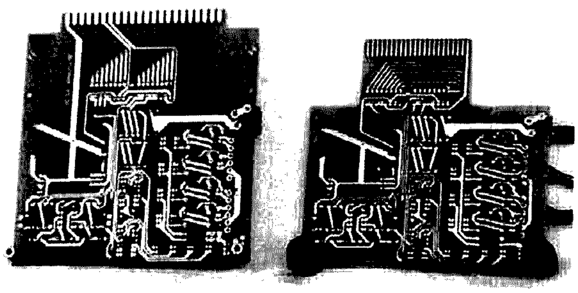


Photo B. Bottom view, VIC-20 and C-64 AUTOTRAK boards. Note two 0.1-k capacitors mounted across pins of LM319 comparators.

Adjust R4 for both red LEDs out with rotor at 90 degrees (straight up).

Warning: always turn the enable switch OFF when the AUTOTRAK board is not in use. If for any reason the computer goes off, the board will have no control and will automatically drive your rotors to one end, leaving the rotor windings energized while trying to find the window. This could eventually damage the windings of the motor.

software

The program lines that need to be added to the "real time" section of your program are very simple. You take the desired azimuth, multiply it by 0.71 to make it fit into the range 0 to 255 (as high as you can count using 8 bits) and POKE it to address 56832 (39936 for the VIC-20). It would look like this:

```
BG=AZIMUTH*.71
POKE 56832,BG
```

Use 39936 instead of 56832 for the VIC-20.

This will work very well for rotors that turn clockwise from north to north again. However, most are set up to travel from south to south, so a 180-degree offset is needed. For a south-to-south rotor, the program lines look like this:

```
BG=(180+AZIMUTH)*.71:
IF BG>255 THEN BG=BG-255
POKE 56832,BG
```

Use 39936 instead of 56832 for the VIC-20.

For elevation bearing, simply multiply your elevation by 1.4 and POKE it to 57088 (38912 for the VIC-20). This gives you a number between 0 and 127 for horizon to straight up, and provides enough accuracy and some safety; in case a number as high as 255 were accidently POKEd, your antenna would move only to the far horizon, not through the roof. The program lines should look like this:

```
EL=ELEVATION*1.4
POKE 57088,EL
```

Use 38912 instead of 57088 for the VIC-20.

A brief but complete program for manual operation of AUTOTRAK using the C-64 is shown in fig. 10.

boards available

Readers who would like to build the AUTOTRAK modules but don't want to make their own boards may order them from me. For $20 each, I'll provide high quality glass epoxy double-sided printed circuit boards with plated-through holes and full assembly instructions. I also have assembled and tested boards as well as world map-style tracking programs for the C-64 and VIC-20 (expanded and unexpanded) that work in real time and are designed to operate the AUTOTRAK boards. The SUPER VR85 mentioned earlier is available from RLD Research. For information on any of these items, please write to me at the address given at the beginning of the article.

acknowledgments

I'd particularly like to thank Al Chandler, K6RFK, Vice President of Engineering for AEA, for taking my prototype drawings and concepts and turning them into a practical design. Thanks also to John Moriarity, K6QQ, and Dick Bartells, WA7ZIH, for their encouragement, suggestions, time, and effort in helping with the preparation of this article.

ham radio

the weekender

a RAM drive for packet radio

Like many Amateurs, I've been spending more time at my computer and less time on the hf or VHF bands. Because packet radio looked like a way to combine both interests and enjoy both activities, I recently purchased a used Heathkit model HD-4040 TNC and decided to try packet radio.

There are times when I found myself missing transmissions, however — or on other occasions, having to wait for activity to pick up. One solution to these problems, I concluded, would be to capture the passing packets onto a disk file and read or print the contents later. But I had no need to fill up floppy disks with transient files; all I wanted was a way to collect and read packets monitored by the computer when I couldn't be there.

A better way, I found, is to divide my random access memory (RAM) into two sections: a storage area (called a RAM drive) and a free section that remains available to the terminal program. I send packets to the RAM drive for storage and read them periodically. One recent 90-minute collection session resulted in the creation of a 20K file for my review.

My frequency-synthesized 2-meter transceiver is connected to the TNC by two cables: one provides audio input and the other enables the microphone connection. The terminal unit contains an internal program (AX.25 protocol) to run the packet receive and packet transmit features for the system. A third cable runs from the TNC to my computer's RS-232 connector

By Thomas M. Hart, AD1B, 54 Hermaine Avenue, Dedham, Massachusetts 02026

```
                  +--------------------+-------------+
                  !                    !             !
                  ! FREE RAM           ! RAM         !
                  !                    ! DISK        !
                  !                    ! DRIVE C>    !
                  +--------------------+-------------+
                          ^                ^
                          !                !
                          !                !
                          !                !
+----------------+        !                +----------------+
!                !--------+                !                !
!DISK            !                         !DISK            !
!DRIVE A>        !                         !DRIVE B>        !
!                !                         !                !
+----------------+                         +----------------+
```

fig. 1. RAM is volatile memory designed to hold programs during execution; a RAM disk is an allocation of memory that simulates a disk drive. Disk drives A> and B> are hardware; drive C> is in software. The operating speed of a RAM drive is much faster than hardware devices like A> and B>; however, when power is turned off, all files in a RAM drive are lost.

(the serial port); the computer acts as a terminal for the packet system.

The computer itself requires a terminal program to permit the computer to "talk" to the TNC; I selected ProComm, a "shareware" program with outstanding features. ProComm has many functions, including one that writes information to a designated file on disk or in RAM for future use.

A RAM drive disappears when the power is shut off; this is not a concern because I use the RAM drive only for capturing information when the system is running and I can't be there. If I need to save a file, it's easy enough to copy the data to one of the regular disk drives.

My RAM drive system is running on a Zenith computer, using MS-DOS version 3.2. However, the same basic approach should work on a wide range of computers using DOS 2.0 or above. Some older versions of MS-DOS may not have a RAM drive file; if yours doesn't, you should be able to obtain one from any users' group.

customizing the RAM

The steps I took in customizing a RAM drive are described below; you should be able to follow the same approach on your own system.

My ProComm working disk is self-booting. An AUTOEXEC.BAT file starts the program. A CONFIG.-SYS file on the disk consists of a single line:

DEVICE = VDISK.SYS.

This cryptic statement sets up the RAM drive when the computer is booted.

The following statement appears when my computer starts up:

Microsoft RAMDrive version 3.2 VIRTUAL disk c:
Disk size: 256 KB
Sector size: 256 bytes
Allocation unit: 1 sectors
Directory entries: 64

If you've never prepared a CONFIG.SYS file, the process is simple; just place the terminal program in the default disk drive. When the DOS prompt appears on the screen, enter the following commands:

A>COPY CON:CONFIG.SYS (RETURN)
DEVICE = VDISK 256 256 (RETURN)
F-6 (FUNCTION KEY 6)

These simple steps will create a new file on the terminal emulation disk. If you want to check the file, do the following:

A>TYPE CONFIG.SYS (RETURN)

The contents of the file will be printed on the screen and should state:

DEVICE = VDISK.SYS 256 256

Copy the file VDISK.SYS from your DOS disk (probably on disk 2) to the terminal disk. This is the RAM disk program, which is installed by the newly created CONFIG.SYS file when the computer is booted.

With the terminal program still in the default drive, reboot the system. This will start the program normally and set up the RAM drive in the process.

When the packet system is running, use the command that your program requires to write information to a file (i.e., the file download command). In ProComm, the commands are:

PAGE-DOWN	(start download)
ASCII FORMAT	(create text file)
ENTER FILE NAME	(I use C:\P)

These few steps will send all packets that the system monitors off to a single file (P) on the RAM drive (C:\). You'll find the system very convenient for passive packet monitoring, and there'll be no reason to miss any of the action in your area.

ham radio

design an amplifier around the 3CX1200A7

Try this logical approach for correct operation

The 3CX1200A7 high-μ triode was introduced about three years ago by the Salt Lake City division of Varian/EIMAC* as an extension of a series of zero-bias tubes of the kilowatt variety. Used predominantly in grounded-grid applications, the '1200 owes its electronic design to the 3-1000Z, which is its direct ancestor. It is a new type, however: air-cooled, possessing slightly different electrical characteristics, but offering increased plate dissipation. Its most notable differences are the anode construction and the resulting increased inter-electrode capacitances. Also, its maximum rated plate voltage is 500 volts less than that of the 3-1000Z.

I bought one of these tubes during the initial EIMAC sales promotion. What follows is a summary of the results of my efforts to generate, for my personal use, design methods for the 3CX1200, as well as for other tubes. Approximately two years of intermittent work were dedicated to this project.

In addition to the published tube characteristics, several aids are available to help designers; some of these were used in the preparation of this work.[1,2] The methods and numbers were transformed, drastically in some cases, without affecting either their content or their applicability. In their places are a few BASIC programs and several figures that greatly reduce the amount of effort necessary to complete a design. Graphs are presented for those without access to a personal computer.

how do we start?

Initially, the following five parameters must be determined: drive impedance and drive power, dc plate current and power input, PEP output, plate dissipation, and plate load resistance. Later, we'll determine air cooling requirements, input matching circuits, and output matching circuits.

*Varian EIMAC, 1678 Pioneer Road, Salt Lake City, Utah 84104.

Figure 1 shows a stylized version of the constant-current curves supplied by the manufacturer for design purposes. Representative of all curves of the type, it provides information we can use to make very good estimates of operating parameters. **Reference 2** provides the standard expressions for them. For "two-tone" conditions, the most important approximations are:

dc plate current, $I_b = 2i_p/\pi^2$, **(1)**

plate input (watts), $P_{in} = 2i_pE_b/\pi^2$, **(2)**

average output (watts), $P_o = i_pe_p/8$, **(3)**

PEP output (watts), $P_o = i_pe_p/4$, and **(4)**

plate efficiency, $E_{ff} = (e_p/E_b)(\pi/4)^2$. **(5)**

Two-tone calculations, which appear throughout this article, are more representative — though not precisely — of single-sideband voice operating conditions. In any event, the PEP output is the same for both two-tone and single-tone conditions.

Figure 1 shows that the points i_p and Q are at opposite ends of a load line. Q represents the quiescent condition of no drive. Therefore the plate voltage is exactly the supply voltage, E_b. The value of the quiescent plate current is also determined. At the other end of the load line is the point i_p, representing the maximum instantaneous plate current (i_p), the minimum instantaneous plate voltage E_{min}, and the peak grid voltage. The positions of these points are arbitrary; the plate supply voltage is what you have available, and the peak plate current (i_p) is your choice. The latter affects the plate load resistance, drive power, drive impedance, PEP output, and virtually everything else of consequence.

The dc plate current may be estimated by the use of **eqn. 1. Equations 2** through **5** will yield other essential numbers. The grid current, however, isn't usually available from the curves. It can be calculated by using the EIMAC Tube Performance Computor[3] or by calculating the transfer curve up the load-line and then integrating the grid current.

By W. J. Byron, W7DHD, P.O. Box 2789, Sedona, Arizona 86336-2789

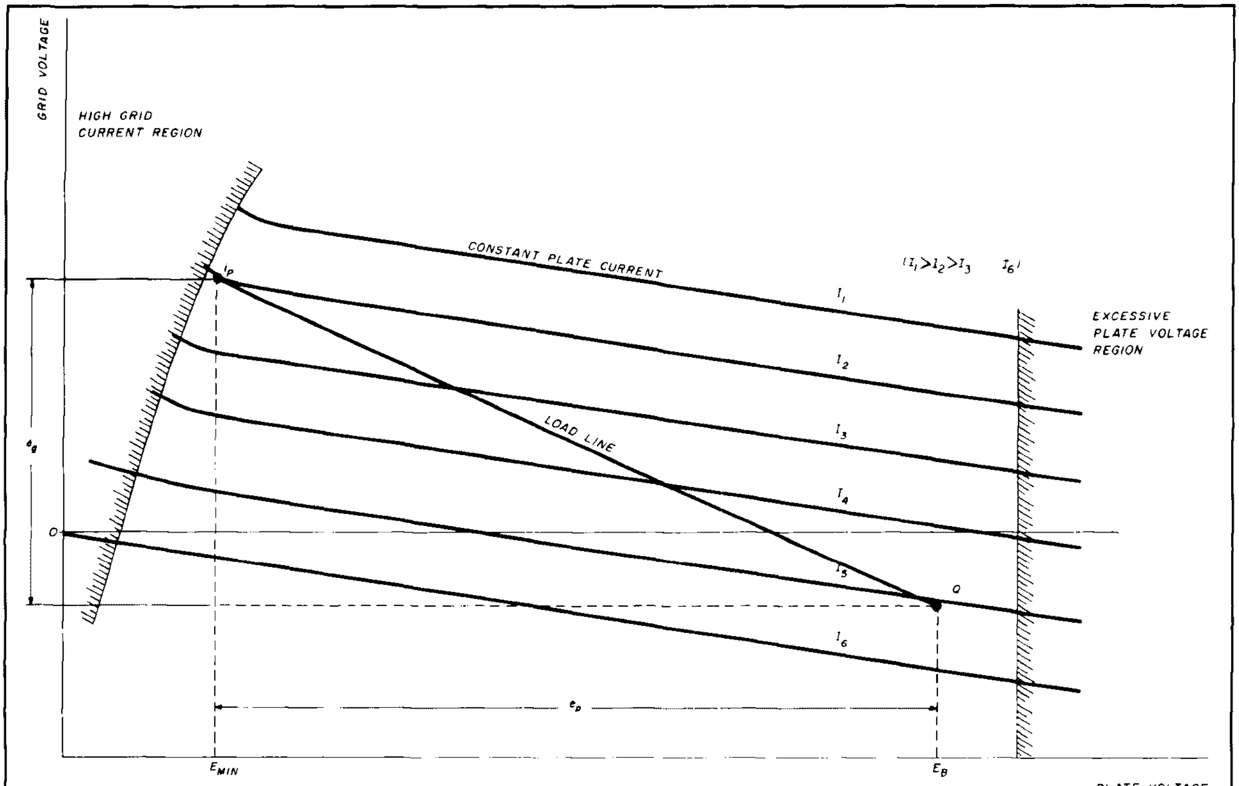


fig. 1. Stylized constant current characteristics.

Neither the transfer curve nor the grid current calculations, which were done on a personal computer, are obvious in the text. I've tried to produce a simple design method that will assure safe operation of this expensive tube if these voltages, currents, and drive power requirements (and restrictions) are met. In the preparation of the graphs and programs included, I first performed an integration up the worst-case loadline. As a result, I've limited the minimum plate voltage to 500 volts; because this limitation is essential to the protection of the grid, it must remain. Thus the designs developed from this article will always yield less — though not much less — than the absolute maximum power available from the 3CX1200A7. It's still possible to achieve considerably more than the maximum legal Amateur power output with relatively low plate-supply voltages, yet operate in a safe, conservative manner.

Figure 2 shows a BASIC program for solving **eqns. 1** through **5**, as well as others. It contains two loops, one of which is nested. The outer loop steps the plate supply voltage from 4000 volts to 2500 in steps of −500 volts. The inner loop steps the max i_p from 1.0 to 2.5 amperes in steps of 100 milliamperes. Thus, as shown, it will produce four tables, each with 16 lines. One table (or "panel") is shown in **fig. 3**. It was printed singly by changing **line 10** to read, "**FOR EB** = 4000 TO 4000". Great latitude is allowed in the loop-control (**FOR-NEXT**) statements. Plate supply voltage may be stepped in units of −500 (as shown), −250, or even −100 volts. Each step will produce one panel. The plate instantaneous maximum current may be stepped in units as low as 1 milliampere. Adjust them according to your needs, but keep the plate voltage at 4000 volts or less, and keep i_p equal to or less than 2.5 amperes. Leave E_{min} at 500 volts.

The reasons for the restrictions are two-fold. First, in order to keep these BASIC programs simple, all programming "traps" were omitted. Steps that would prohibit plate voltages over 4000, and plate currents of over 2.5 amperes, for example, would only complicate the programs; while they're necessary in other circumstances, they probably aren't appropriate here. The other is that the maximum values are those which have been established by the work described earlier.

By selecting an appropriate plate supply voltage, the program will produce 16 lines that list all data consistent with that voltage. One hundred watts drive at a plate voltage of 4000 predicts a PEP output of approximately 1800 watts — see **fig. 3**. The data for exactly 100 watts drive fall between the i_p values of 2.00 and 2.10 amperes. If you want a more precise answer than

```
5 REM SAVED AS 1200B
10 FOR EB = 4000 TO 2500 STEP 500
20 EM = 500
30 LPRINT"================================================================"
40 LPRINT"              3CX1200A7 TWO-TONE; EB =";EB;" Volts"
41 LPRINT"                        GROUNDED GRID"
50 LPRINT"                       Emin. = ";EM;" Volts"
60  IF EB >= 3500 THEN LPRINT"                  (Fixed Bias = 16 Volts)"
70  IF EB >=3000 AND EB<3500 THEN LPRINT"               (Fixed Bias=8.2 Volts)
80 IF EB >=2500 AND EB<3000 THEN LPRINT"                (Fixed Bias=8.2 Volts)
90 IF EB < 2500 THEN LPRINT"                            (Zero Bias)
100 LPRINT"-----------------------------------------------------------------"
110 LPRINT"  ip    Zi   Pdrive   ep     Ib    DC in    PEP   Pl.Dis.  RL"
120 LPRINT" Amps  Ohms  Watts   Volts  Amps   Watts   Watts   Watts  Ohms"
130 LPRINT" ----  ----  ------  ----  -----  ------  ------  ------  ----"
140 FOR IP =1! TO 2.5 STEP .1
150 IF EB =>3500 THEN EK= 51! -4.16666*IP+20*IP^2-3.3333*IP^3
160 IF EB>=3000 AND EB<3500 THEN EK= 43.2 -4.16666*IP+20*IP^2-3.3333*IP^3
170 IF EB>=2500 AND EB<3000 THEN EK= 43.2 -4.16666*IP+20*IP^2-3.3333*IP^3
180 IF EB  <2500 THEN EK= 35! -4.16666*IP+20*IP^2-3.3333*IP^3
190 PI=3.14159
200 IB = 2*IP/(PI^2)
210 EP = EB-EM
220 PFT = EK*IP/4
230 PEP =(IP*EP/4)+PFT
240 ETA = (EP/EB)*(PI^2/16)
250 ZI = 2*EK/IP
260 RL = 2*EP/IP
270 PD = EK^2/ZI
280 WI = IB*EB
290 DIS = (WI)*(1-ETA)
300 A$= "##.## ###.#  ###.##  ####  #.###  ####.#  ####.#  ####.#  ####"
310 LPRINT USING A$;IP;ZI;PD;EP;IB;WI;PEP;DIS;RL
320 NEXT IP
330 LPRINT"-----------------------------------------------------------------"
340 LPRINT"  Note: Overall Plate Efficiency is ";INT(10000*ETA)/100;" per cent."
360 LPRINT"           Drive feed-through is added to PEP out."
400 LPRINT:LPRINT
410 NEXT EB
420 END
```

fig. 2. BASIC program solves eqns. 1 through 5, plus others, producing tables of tube operating parameters.

```
============================================================
          3CX1200A7 TWO-TONE; EB = 4000  Volts
                    GROUNDED GRID
                  Emin. =  500  Volts
                (Fixed Bias = 16 Volts)
------------------------------------------------------------
```

ip Amps	Zi Ohms	Pdrive Watts	ep Volts	Ib Amps	DC in Watts	PEP Watts	Pl.Dis. Watts	RL Ohms
1.00	127.0	31.75	3500	0.203	810.6	890.9	373.1	7000
1.10	120.3	36.40	3500	0.223	891.6	980.7	410.4	6364
1.20	115.1	41.42	3500	0.243	972.7	1070.7	447.7	5833
1.30	110.9	46.84	3500	0.263	1053.7	1160.9	485.0	5385
1.40	107.5	52.65	3500	0.284	1134.8	1251.3	522.3	5000
1.50	104.7	58.88	3500	0.304	1215.9	1341.9	559.6	4667
1.60	102.4	65.50	3500	0.324	1296.9	1432.8	596.9	4375
1.70	100.4	72.54	3500	0.344	1378.0	1523.8	634.2	4118
1.80	98.7	79.97	3500	0.365	1459.0	1615.0	671.5	3889
1.90	97.3	87.80	3500	0.385	1540.1	1706.4	708.8	3684
2.00	96.0	96.00	3500	0.405	1621.1	1798.0	746.1	3500
2.10	94.8	104.56	3500	0.426	1702.2	1889.8	783.4	3333
2.20	93.8	113.45	3500	0.446	1783.3	1981.7	820.8	3182
2.30	92.7	122.66	3500	0.466	1864.3	2073.8	858.1	3043
2.40	91.8	132.14	3500	0.486	1945.4	2166.1	895.4	2917
2.50	90.8	141.88	3500	0.507	2026.4	2258.4	932.7	2800

```
------------------------------------------------------------
 Note:  Overall Plate Efficiency is  53.97  per cent.
          Drive feed-through is added to PEP out.
```

fig. 3. Example of the output of the BASIC program of fig. 2.

these, change **line 140** to read, "FOR ip = 2.0 TO 2.1 Step .01". Then you'll get one panel with eleven lines, representing conditions for drive powers from 96.0 to 104.56 watts. Remember that the supply voltage is a "loaded" value; that is, the plate voltage under load. Typically, it will be between 5 and 10 per cent below the no-load value.

A prospective builder probably has only a few factors under control at the outset of a design. He has the tube, an exciter, a power transformer or a power supply, and maybe a surplus centrifugal blower. He therefore has only two pertinent inputs; plate-supply voltage and drive power. It's possible to rearrange the program to accommodate only those two inputs.

While the program shown in **fig. 2** can do all that's necessary, it was modified so that those two factors are the only inputs; **fig. 4** lists that program. First it requests "PLATE SUPPLY VOLTAGE," and "MAX DRIVE POWER." It then begins with an i_p of 1 ampere and incrementally steps the value, in this case by 5 milliamperes, and calculates Z_I and P_D (drive impedance and drive power). It then compares the calculated P_D until it's in a "window" of $A \pm 0.5$ watts width, where A is the exciter drive power. When this is reached, it then performs all the other calculations and produces one panel with one line — the only one that meets the requirements of the inputs. Though it doesn't print a hard copy, one can be obtained by using the screen dump facility (mine is simply SHIFT/PRINT.) An example of the program output is shown in **fig. 5**.

At this point it's very important to emphasize that although modern exciters are of the "100-watt PEP minimum" variety, many — and perhaps most — will exceed 100 watts PEP output. The programs above require that the designer know the charactistics of the exciter. It isn't good design if one enters 100 watts for the PEP drive power, when in reality it might be 120 watts. Almost all exciters will deliver more PEP output under voice conditions than they will under "key-down" on CW. The leading cause of power-grid tube destruction is excessive grid dissipation. The most important single instrument in an amplifier is the grid-current meter.

completing the design

The major difference between the '1200 and the 3-1000Z is in the cooling, another factor not yet faced. If you have a surplus blower in the shack, it's essential to know beforehand if it will be sufficient. The best way to determine this is to test the blower in a separate measurement.

Find a cardboard carton large enough to hold the tube, and sturdy enough to allow the blower to be taped onto the side. Cut a circular hole large enough

```
10 REM SAVED AS 1200X
20 INPUT "PLATE SUPPLY VOLTAGE";EB
30 INPUT "MAX DRIVE POWER";A
40 EM = 500
50  PRINT"=============================================================="
60  PRINT"              3CX1200A7 TWO-TONE; EB =";EB;" Volts"
70  PRINT"                       GROUNDED GRID"
80  PRINT"                      Emin. = ";EM;" Volts"
90  IF EB >= 3500 THEN  PRINT"                    (Fixed Bias = 16 Volts)"
100  IF EB >=3000 AND EB<3500 THEN  PRINT"                 (Fixed Bias=8.2 Volts)"
110 IF EB >=2500 AND EB<3000 THEN  PRINT"                  (Fixed Bias=8.2 Volts)"
120 IF EB < 2500 THEN  PRINT"                        (Zero Bias)"
130  PRINT"--------------------------------------------------------------"
140  PRINT" ip    Zi   Pdrive   ep     Ib    DC in    PEP   Pl.Dis.  RL"
150  PRINT" Amps  Ohms  Watts   Volts  Amps   Watts   Watts   Watts  Ohms"
160  PRINT" ----  ----  ------  ----   -----  ------  ------  ------ ----"
170 IP=1
180 IF EB =>3500 THEN EK= 51 -4.16666*IP+20*IP^2-3.3333*IP^3
190 IF EB>=3000 AND EB<3500 THEN EK= 43.2 -4.16666*IP+20*IP^2-3.3333*IP^3
200 IF EB>=2500 AND EB<3000 THEN EK= 43.2 -4.16666*IP+20*IP^2-3.3333*IP^3
210 IF EB  <2500 THEN EK= 35 -4.16666*IP+20*IP^2-3.3333*IP^3
220 ZI = 2*EK/IP
230 PD = EK^2/ZI
240 IF PD=>(A-.5) AND PD=<(A+.5)THEN 260 ELSE 250
250 IP = IP+.005:GOTO 180
260 PI=3.14159
270 IB = 2*IP/(PI^2)
280 EP = EB-EM
290 PFT = EK*IP/4
300 PEP =(IP*EP/4)+PFT
310 ETA = (EP/EB)*(PI^2/16)
320 RL = 2*EP/IP
330 WI = IB*EB
340 DIS = (WI)*(1-ETA)
350 A$= "#.### ###.# ###.## #### #.### ####.# ####.# ####.# ####"
360  PRINT USING A$;IP;ZI;PD;EP;IB;WI;PEP;DIS;RL
370  PRINT"--------------------------------------------------------------"
380  PRINT" Note:  Overall Plate Efficiency is ";INT(10000*ETA)/100;" per cent."
390  PRINT"        Drive feed-through is added to PEP out."
400  PRINT: PRINT,
410 END
```

fig. 4. BASIC program modified to accept two inputs, plate supply voltage, and PEP drive power.

```
RUN
PLATE SUPPLY VOLTAGE? 3250
MAX DRIVE POWER? 110
==============================================================
           3CX1200A7 TWO-TONE; EB = 3250  Volts
                   GROUNDED GRID
                  Emin. =  500  Volts
                 (Fixed Bias=8.2 Volts)
--------------------------------------------------------------
 ip     Zi    Pdrive    ep     Ib     DC in    PEP   Pl.Dis.  RL
 Amps   Ohms  Watts    Volts  Amps    Watts   Watts  Watts   Ohms
 ----   ----  ------   ----   -----   ------  ------ ------  ----
 2.255  86.3  109.69   2750   0.457   1485.1  1605.2  710.0  2439
--------------------------------------------------------------
   Note:  Overall Plate Efficiency is  52.19  per cent.
          Drive feed-through is added to PEP out.

Ok
```

fig. 5. Example of the output of fig. 4.

✓ 230

✓ 231

```
10 REM SAVED AS "AIR-4" - WORKS FOR BOTH 3CX1500A7 (8877) AND 3CX1200A7
20  PRINT"ENTER '1' FOR 3CX1200A7 OR '2' FOR  3CX1500A7/8877"
30 INPUT "1200 OR 8877";A$
31 IF A$ <"1" THEN 30
32 IF A$ >"2" THEN 30
35 IF A$ = "" THEN 30
40 INPUT "WHAT IS THE CALCULATED PLATE DISSIPATION (KW)";PW
50 IF A$ = "1" THEN 70
60 IF A$ = "2" THEN 80
70 PD = -9.999991*.001+7.266617*.01*PW+.088*PW^2+.149333*PW^3:GOTO 100
80 PW = PW*1000
90 PD = .00031*PW - 3.6*.0000001*PW^2 + 2.8*1E-10*PW^3
100 INPUT "WHAT TEMPERATURE (DEGREES CELSIUS)";T
110 Q1 = .91502 +3.398895E-03*T + 2.980232E-08*T^2 - 4.656613E-10*T^3
120 INPUT "WHAT IS YOUR ALTITUDE (FEET ABOVE SEA-LEVEL)";A
130 Q2 = .9999999 + 3.333335E-05*A + 1.400004E-09*A^2 - 1.33333E-14*A^3
140 H = INT(100*PD*Q1*Q2+.5)/100
150 PRINT "THE MANOMETER READING AT THESE CONDITIONS IS";H;"IN. WG"
160 END
RUN
ENTER '1' FOR 3CX1200A7 OR '2' FOR  3CX1500A7/8877
1200 OR 8877? 1
WHAT IS THE CALCULATED PLATE DISSIPATION (KW)? .710
WHAT TEMPERATURE (DEGREES CELSIUS)? 50
WHAT IS YOUR ALTITUDE (FEET ABOVE SEA-LEVEL)? 4300
THE MANOMETER READING AT THESE CONDITIONS IS .18 IN. WG
Ok
```

fig. 6. BASIC program to calculate air differential pressure across tube anodes for both the 3CX1200A7 and the 3CX1500A7 (8877). It is valid for temperatures from zero to 50 degrees C, and for altitudes from sea level to 15,000 feet.

to hold the tube anode; but tight enough to hold the tube by friction alone. With masking tape, tape the tube in place. Now do the same for the blower. Tape all seams so that the system is tight.

Make a water manometer using Tygon™ tubing of at least 3/16 inch ID. (Be sure to use tubing large enough to prevent a meniscus problem.) Push one end of the tubing into the box and tape it in place. Add one drop of food coloring for visibility, and one drop of liquid detergent to the water to aid surface-wetting. Then start the blower. The vertical difference between the two levels in the manometer is the δP in inches w.g. If the levels don't return to zero differential after the blower is turned off, the measurement is probably faulty, and you should find tubing of a larger diameter.

The differential pressure required is a function of power dissipation, ambient temperature of the inlet air, and its density (altitude). **Figure 6** shows a BASIC program that calculates the δP for both the 3CX1200A7 and the 8877. The solution is based on **fig. 5** and my QTH, which is 4300 feet above sea level. An ambient temperature of 50 degrees C is conservative — and this should be the designer's goal. For 710 watts plate dissipation and an altitude of 4300 feet, the required differential pressure is 0.18 inches w.g. That's the minimum acceptable reading; because overcooling prolongs tube life, I'd strive for 0.2 or 0.25 inches for this QTH. Don't accept anything less than the calculated number at your QTH. It is assumed — and essential — that the manufacturer's recommended socket and chimney be used.

The manufacturer permits zero-bias operation of the '1200 even for plate supply voltages up to 4000. The plate quiescent power dissipation under this condition is 900 watts! See what that does to the calculations in the paragraph above. That is the main reason for bias voltages (Zeners) up to 16 volts in both programs and graphs.

Figures 7, 8 and **9**, derived from the programs, are included as guides for those without a personal computer. They're usable, provided the exciter PEP doesn't exceed the 110 watts specified in the figures.

The hypothetical design in **fig. 5** gives a cathode drive impedance of 86.3 ohms, a PEP output of 1605 watts, and a plate load resistance of 2439 ohms (round off to 2440). These are for a drive power of 110 watts and a plate supply voltage of 3250. Now we can design the input and output matching circuits.

cathode drive circuit

The calculations were all done for grounded-grid

operation. The computed drive impedance at the cathode is, for the example, 86.3 ohms. Since the 3CX1200 is a filament-type tube, it requires a filament choke, and a hefty one at that, because the filament current is 21 amperes. The rule of thumb for such devices is that the reactance of the choke (a bifilar filament choke) must be no smaller than 5 • 83.8 ohms. Assume about +j500 ohms at the lowest frequency contemplated; 86.3 ohms in parallel with +j500 ohms equals 83.8 + j14.5 ohms, which is easily compensated by a Pi-section. The problem desolves to the design of an impedance matching circuit that converts 50 ohms to 84 ohms. I recommend a Pi-section with a Q_r of about 3.5. The reactance values appear in **fig. 10**.

output matching

The plate load resistance from the program is 2440 ohms. There are many ways to match that to 50 ohms. The example worked out here will be the PI-L, which is just what it implies: a Pi-section followed by an L-section. The Pi converts the resistance (or impedance) to an intermediate value, and the L further converts it to the desired 50-ohm load. The intermediate impedance (the junction between the L and the Pi) is, by convention, between 10 and 15 percent of the input impedance. A typical value would be 300 ohms. The attractiveness of the PI-L is in that it has a series inductance in the output side, and provides greater harmonic attenuation than the usual PI-section. Methods for designing both Pi- and L-sections are available from many sources. The reactance values for the Pi-L also appear in **fig. 10**.

Harmonic attenuation, however, is greatly dependent on the Q of the tank circuit, no matter what type is used. It should be somewhere between 15 and 20 for the lower frequencies, but because of distributed circuit capacitances it may be forced above 20 at, say, 29 MHz. The reason is that the component capacities to ground (switches, busses, and coils) plus the out-

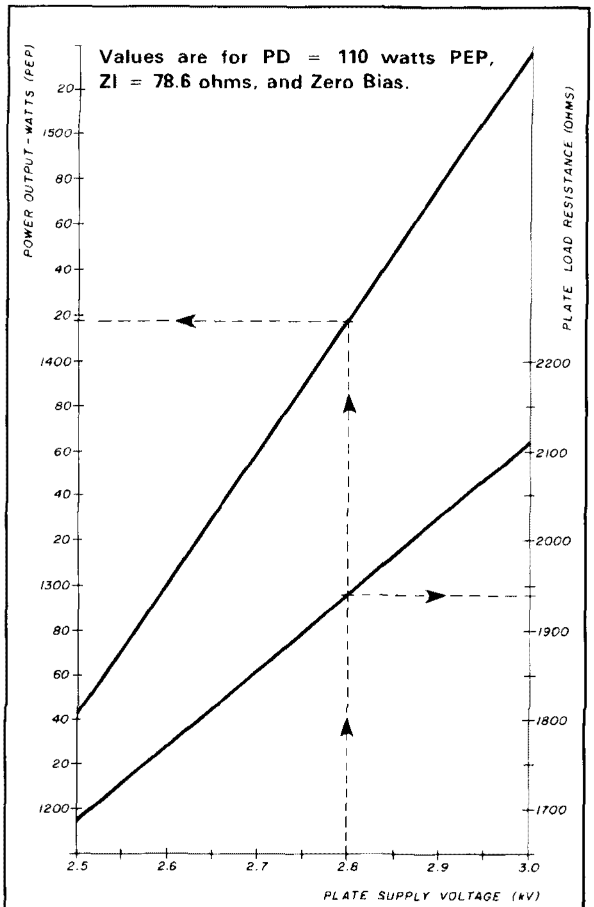


fig. 7. Amplifier parameters for plate supply voltages from 2.5 to 3.0 kV.

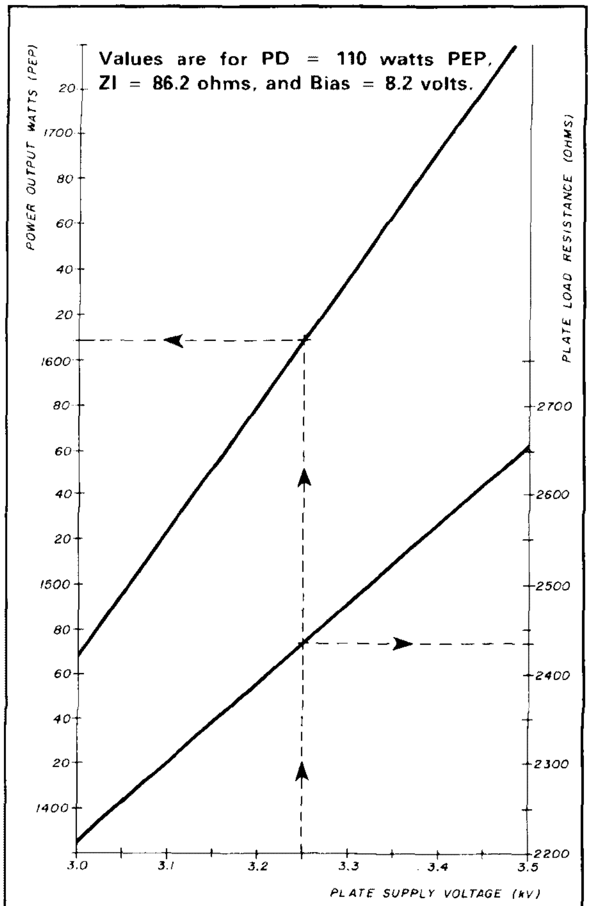


fig. 8. Amplifier parameters for plate supply voltages from 3.0 to 3.5 kV.

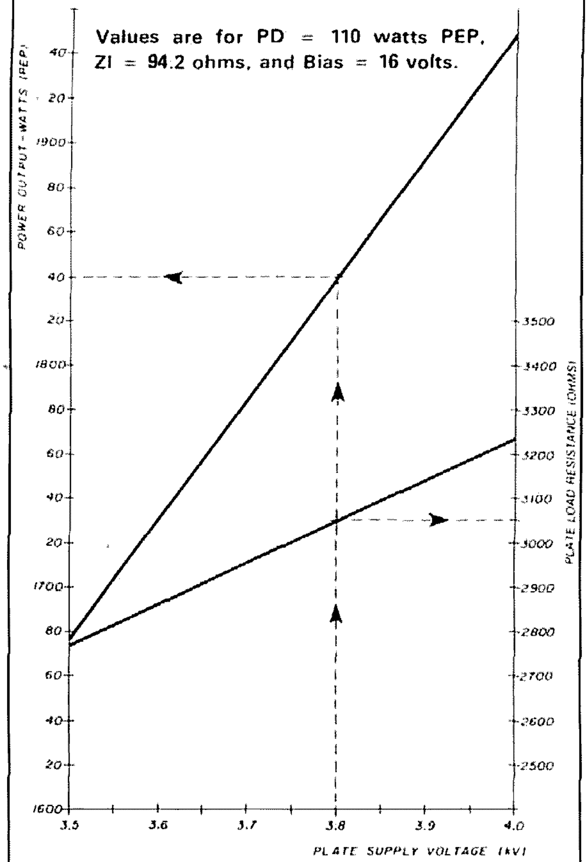


fig. 9. Amplifier parameters for plate supply voltages from 3.5 to 4.0 kV.

put capacitance of the tube itself frequently constitute the major part of the total input capacitance of the tank circuit. To give the tuning capacitor more control over resonance, a higher Q usually is selected. Try a Q of 25 as a first guess for the 10-meter band.

operation

When the design is completed and the construction is nearly finished, I find that an additional step is extremely valuable. For example: the design is based on a Q of 15 and a load resistance of 2440 ohms. But when a load (near 50 ohms) is placed on the output, it's possible to "load" the amplifier with many positions of the input and output capacitors. Which ones are correct?

The programs developed and the background work done require that the amplifier be operated according to design. There is only one value each for C_1 and C_2 in the PI-L tank that will assure that the plate is looking at 2440 ohms. There is an easy way — and a rela-

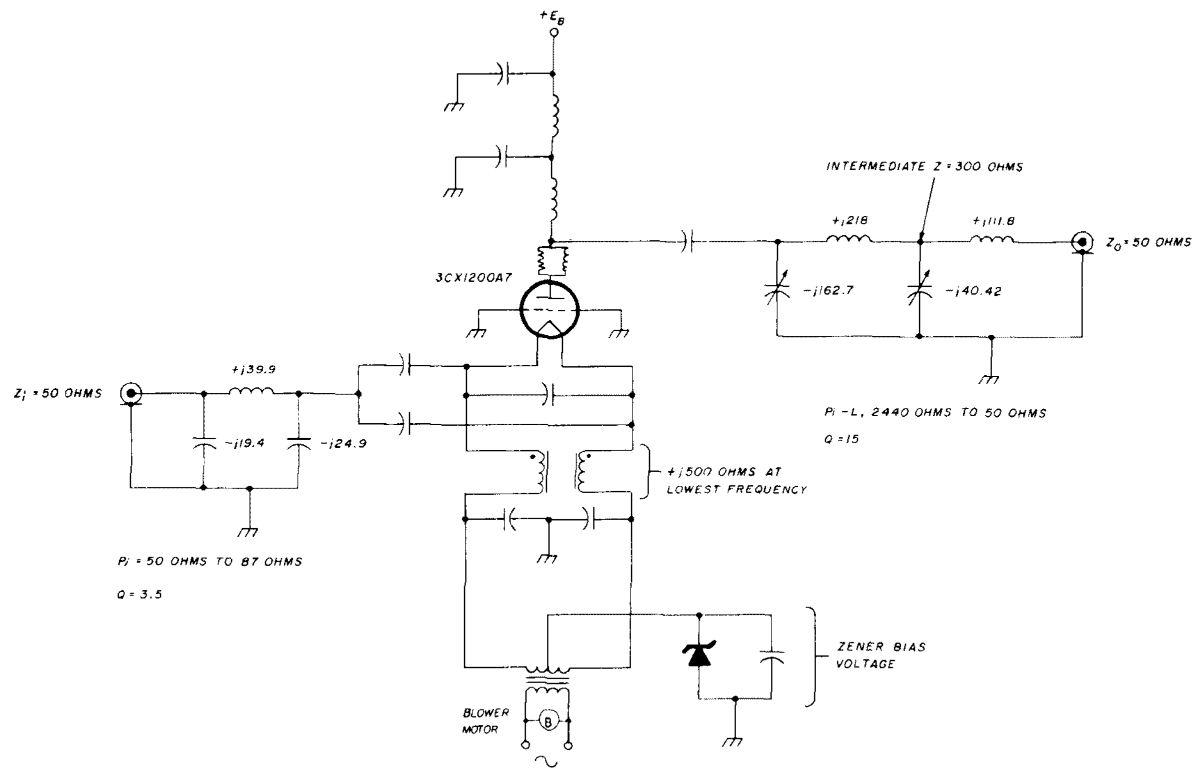


fig. 10. Input, output, and cathode partial circuitry. The reactance values shown are the ones necessary to meet the design conditions specified in the text and in the figure.

looking at 2440 ohms. There is an easy way — and a relatively precise one — to determine beforehand what these are.

A method I have used for years requires only a noise bridge and some carbon (non-inductive) resistors. Series-parallel combinations are perfectly acceptable. First, balance the noise bridge with a 50-ohm resistor. Then, without touching either the R or X knobs (leave the bridge at the balance position), connect the "Unknown" port to the output of the amplifier. Temporarily connect a 2440-ohm resistance from the plate to ground. Adjust $C1_1$ and $C2_2$ until the bridge is again balanced. Those are the correct settings for the amplifier during operation. Mark their position on the dials or the panel. Just so that there's no misunderstanding, *leave all amplifier voltages off during this test!* The same methods are very useful in adjusting baluns, transmission-line transformers, and transmatches — which I recommend using no matter what is on the other side of the transmatch. If the amplifier is looking at something other than 50 ohms, the measurements, regardless of how carefully they've been made, mean very little.

conclusion

The programs and methods presented here are simplified versions of those I've developed over the past two years or so, but which are too complicated to be presented in full. The 3CX1200A7 is a new tube type that is of interest to Amateurs, and the simpler programs offer a way to help interested hams to do some design work of their own. I've also described some techniques (fan-testing and the pretuning of an amplifier) which should be useful in other projects. I built an amplifier about six years ago that used a variometer-type link coupling. If it weren't for the special use of a noise bridge, I would never have been able to determine for certain where the proper load conditions were. I hope these hints and techniques will be useful to you, too.

references

1. *Amateur Single Sideband*, Ham Radio Publishing Group, Greenville, New Hampshire 03048.
2. "Care and Feeding of Power Grid Tubes," Laboratory Staff, Varian EIMAC, 1678 Pioneer Road, Salt Lake City, Utah 84104.
3. "Tube Performance Computor (or their specific brochure title)." Bulletin No. 5, Varian EIMAC, 301 Industrial Way, San Carlos, California 94070.

ham radio

PRACTICALLY SPEAKING ... Joe Carr K4IPV

generating low i-f frequencies from an hf signal generator .

Like many Amateurs, I own several older signal generators that were once used in engineering laboratories, professional service shops, or maintenance repair organizations (MROs), and other places where high-quality rf signal sources are needed. Mine was traded from a local Amateur for a broken SB-34; he'd rescued it from the dumpster in back of our engineering school. That old Measurements Model 80 still has plenty of life in it, and works a lot better than some of the cheap signal generators that I could afford brand new.

Amateurs who want to build a collection of good test equipment often do well with these industry castoffs. I've seen top-of-the-line instruments from Boonton, Hewlett Packard, Measurements, Inc., and other notable manufacturers at hamfests for prices that were quite low. A very clean Boonton 202H am/fm/CW signal generator (which covers the 220-MHz band) was offered for only $50 because the frequency range was, at the time, of less interest than other ranges. Similarly, an HP 608 in apparently good shape fetched only $175.

But there's a problem with my Model 80 and many other signal generators. Though they work well on hf and VHF, they don't provide signals below hf. My Model 80, for example, operates over the range of 2 to 400 MHz. Yet there are times when I'd want it to provide signals in the lower end of the spectrum – above audio, but less than 2 MHz. For example, how do you align or troubleshoot a 455 kHz i-f amplifier without a good signal generator?

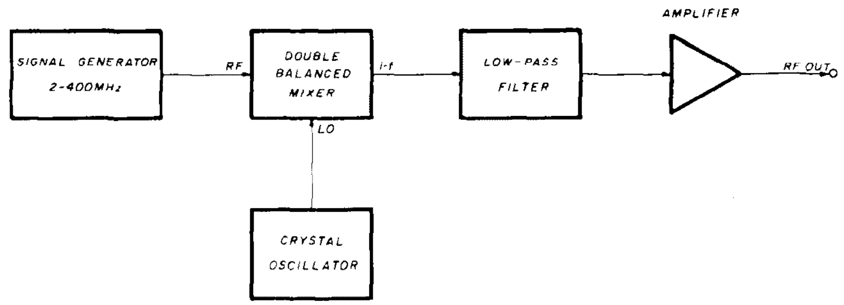


fig. 1. Low-frequency signal generator block diagram.

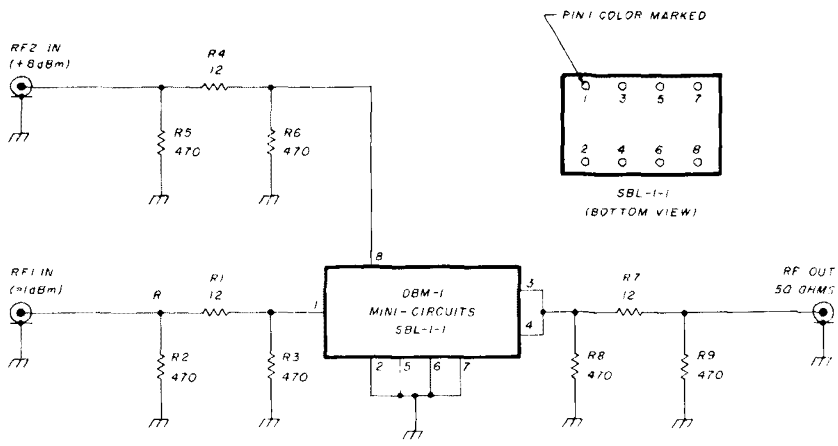


fig. 2. Attenuator helps isolate DBM from load variations.

Some instrument manufacturers addressed that need with separate signal generators that had overlapping ranges. I suspect that was a sales strategy to get us to buy two instruments instead of one (some makers did, however, offer "full range" signal sources inside a single box). Others, such as Boonton (later bought out by Hewlett-Packard), offered additions such as the Univerter. That interesting device took the output of the Boonton 202 series of signal generators and down-converted it to a frequency between 10 kHz and 2 MHz, at the same rf level that was input. This latter feature allowed the user to set the rf level with the master attenuator on the front panel.

A basic but effective method of solving the problem is by heterodyning the output of the signal generator to a lower frequency. **Figure 1** shows a block diagram of the system. The

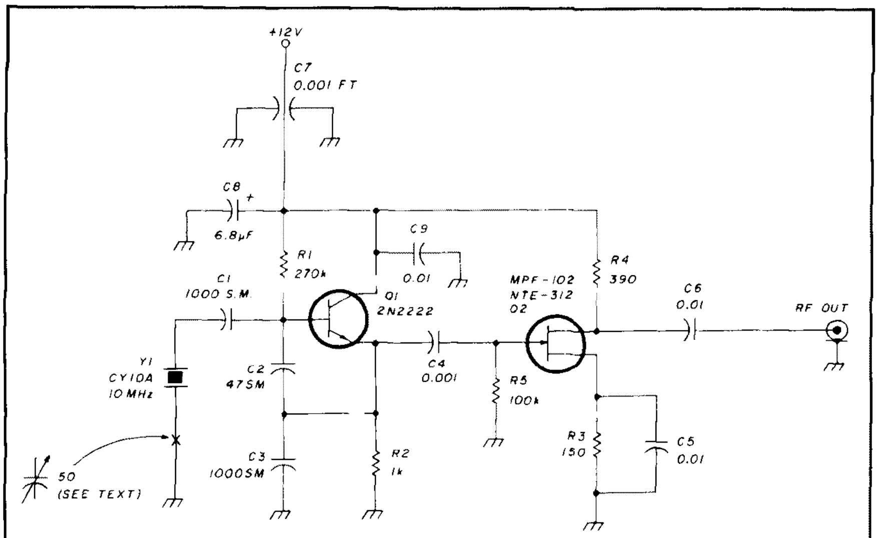


fig. 3. Colpitts oscillator and buffer amplifier combination provide stable source.

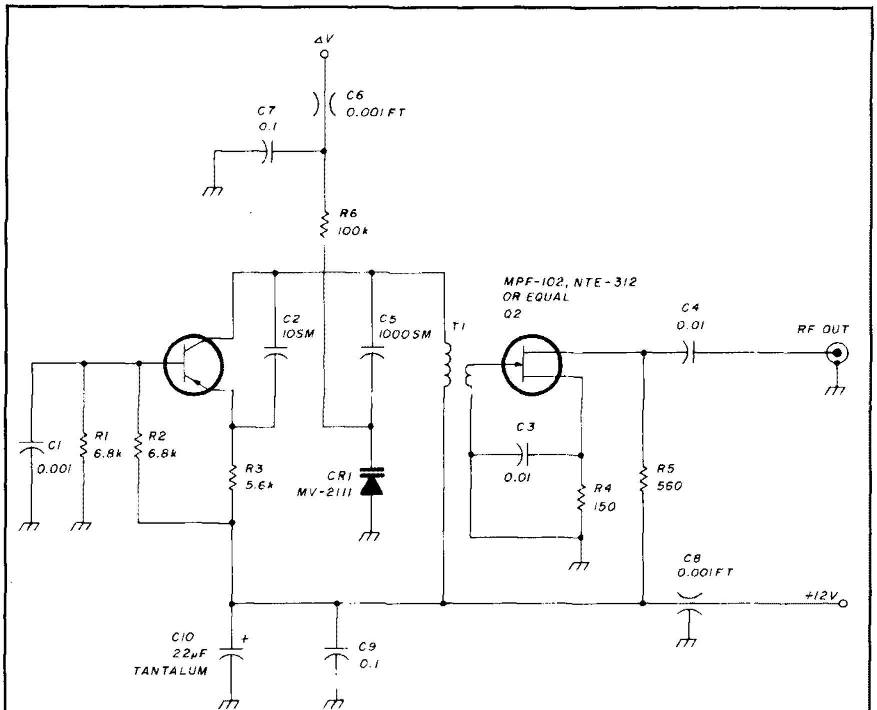


fig. 4. Voltage-tuned oscillator can be tuned from 34 to 40 MHz.

double balanced mixer (DBM) receives the output of the signal generator at its "rf" port, and a stable local oscillator signal at its "LO" port. The difference signal appears at the i-f port. The output of the DBM should be low-pass filtered to remove residual high-frequency signals. In my own case, I wanted to generate frequencies up to 1.9 MHz, so I used a 2-MHz low-pass filter described in reference one.

The amplifier at the output of the low-pass filter is optional. I didn't find it necessary for my application because the entire gain of a communications receiver i-f amplifier was behind the signal generator. For others, however, some form of amplifier is recommended. Perhaps the easiest approach to a wideband (2 MHz) amplifier is a bandpass-limited version of the MMIC amplifiers discussed in Joe Reisert's column recently.[2,3,4] These amplifiers are low in cost, easy to construct, and already have a 50-ohm input/output impedance.

construction

Over the past few years I've built several modules on my workbench for use in various projects or as "test gear," and these were usable in this project. These modules are a double-balanced mixer with wideband output, a 10-MHz crystal oscillator, and a 34- to 40-MHz voltage controlled oscillator. The DBM (**fig. 2**) is built from a Mini-Circuits SBL-1-1.* This model of the well-known MCL product is able to work over a range of 0.1 to 400 MHz, which matched my requirements nicely. The inputs and the output terminal are isolated internally with 2-dB resistive attenuators, which are sometimes used in wideband circuits to overcome difficulties that can be caused by changing impedances over a wide frequency range. Because no tuning is used at the i-f output, the DBM of **fig. 2** is wideband. I built it in a die-cast shielded Pomona box that provides a reasonably good seal against rf leakage in or out. The input and output connectors are BNC. The rf input (RF1) will accept signals up to +1 dBm (1.26 mW), while the local oscillator (RF2) input requires +7 dBm (5 mW) to work properly.

The crystal oscillator (**fig. 3**) was originally built for use as a marker (generator) in an alignment job. The 10.7-MHz crystal was subsequently replaced with a 10.00-MHz crystal to allow the oscillator to be used as time-base source in a digital project, and as

* Mini Circuits Laboratories, Inc., P.O. Box 166, Brooklyn, New York 11235

a crystal calibrator in a receiver. The CY-10A 10-MHz crystal was obtained from a Jim-Pack display at a local electronics shop for only a few dollars.*

The oscillator circuit uses a 2N2222 NPN transistor, although almost any replacement rf transistor similar to the 2N2222 will also work well. In fact, I've used this same circuit with both PNP and NPN transistors selected at random from a variety of sources. Although in many cases stability might suffer as a result of a less than rigorous selection of devices, it demonstrates that this circuit is forgiving and easy to construct. The basic circuit is a Colpitts crystal oscillator. The feedback capacitor voltage divider network (C2, C3) should be made from silver-mica capacitors for best stability. This circuit works at frequencies from 2 to 20 MHz.

To enable tuning the crystal frequency to exactly 10.0 MHz, place a 50-pF trimmer capacitor in series with the crystal and eliminate capacitor C1. Adjust the trimmer for exactly 10 MHz output, as measured by a digital frequency counter or by zero-beating WWV.

The output stage is a JFET buffer amplifier. When I found that the oscillator frequency would be pulled slightly when load impedances changed, I decided buffering would be necessary. The JFET is an MPF-102 or equivalent device — for example, an NTE-312, which is widely available from local parts distributors.

The crystal oscillator was built inside a shielded aluminum sheet metal box. Although not as rf-tight as other types of boxes, it is satisfactory. For more critical applications, use die-cast boxes or simply drill a number of extra holes for screws in the sheet metal box (for "buttoning" it up) to improve shielding.

When I needed to generate a 455-kHz signal, I used the 10-MHz crystal oscillator to drive the LO input of the

* Jim-Packs (blister-packed electronics parts) are available at most local hobby and TV service parts distributors. The same components are available in non-blister packed from from Jameco Electronics.

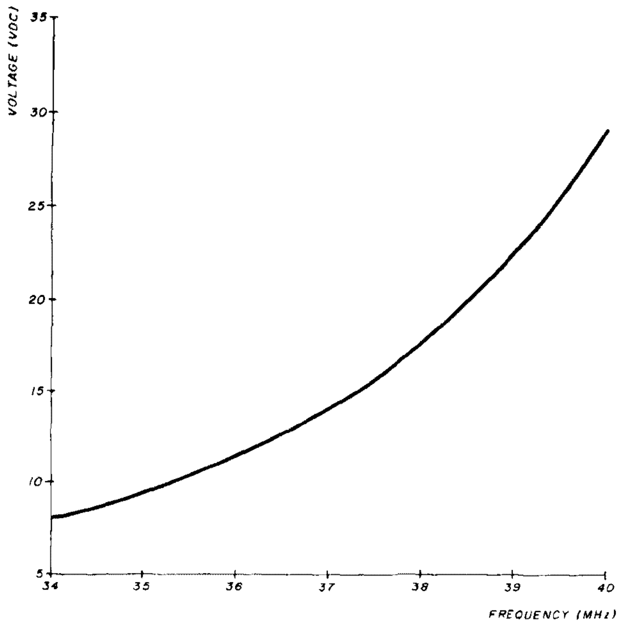


fig. 5. Voltage-tuned oscillator operating range.

DBM module, and the Model 80 signal generator to drive the rf input of the DBM. With a 10-MHz LO, the 0- to 2-MHz output is generated by tuning the signal generator from 10 to 12 MHz.

additional uses

I built a voltage tuned oscillator that operated over a range of 34 to 40 MHz (see **fig.** 4). This circuit is a simple variable frequency oscillator circuit in which part of the capacitance used to tune the tank circuit is derived from a variable capacitance diode ("varactor"). In this case, I used an MV-2111 device, which offers 47 pF at 4 Vdc and a C/C_0 ratio of 2.6:1. The inductor is a 49-MHz TV i-f amplifier transformer (Digi-Key part No. TK-209).*

Figure 5 shows the relationship between tuning voltage and output frequency. Please note that this figure is very rough, and reflects factors such as my choice of layout (stray capacitance), the specific MV-2111 that I used, and the accuracy of the voltmeter and digital frequency meter. Before a curve such as the one shown in **fig. 5** can be trusted completely, it is necessary to build several such identical circuits and calibrate them several times to obtain enough data points to give one confidence in the calibration. For example, a second oscillator was built using the same circuit operated over a range of 32 to 44 MHz, but it had tighter layout on the wireboard. You'll obviously have to experiment and make your own calibration curve, even though it will probably be close to the one shown in **fig 5**. The important thing to note is that there is a relationship between voltage and frequency. If we apply a modulating signal to the tuning voltage input (V), then the output signal is frequency modulated (or swept, if a sawtooth is used). Like the crystal oscillator above, the VCO shown in **fig. 4** uses an output buffer amplifier to prevent varying load impedances from affecting the operating frequency. The buffer is even more important to this circuit than in the crystal oscillator case.

There are two ways to use the VCO. First, we can replace the signal generator at the rf input of the DBM with the VCO. The output of the DBM then

* Digi-Key Corporation, P.O. Box 677, Thief River Falls, Minnesota 56701.

becomes the difference between the 10-MHz crystal oscillator and the VCO, or a range of 24 to 30 MHz. We could, instead, replace the crystal oscillator with the VCO, making the output frequency the difference between the signal generator and the VCO. Because of the wide range of the signal generator, a wide range of sweep center frequencies is possible.

So of what use is a sweep generator? It is possible to sweep an entire Amateur band in order to inspect the frequency response of a circuit. One can also sweep an antenna over a wide range in order to determine resonance. Of course, devices such as bandpass filters are best inspected using a sweep generator. I suspect that many applications should be apparent.

If you use the method described above to sweep tuned circuits, be sure to keep the sweep frequency rate low. A high sweep frequency will ring high-Q tank circuits or filters and cause other problems during measurements. Although audio sine waves to 1000 Hz present no problem, sawtooth, triangle, or squarewave modulation should be kept to 60 Hz or less.

One problem with this circuit is the fact that the output amplitude may not be level over the band swept. In cases where this variation is important, it might prove necessary to use a wideband automatic gain control (AGC) amplifier at the output. But that's a subject for another column, and is one of the topics I'm currently working on.

I'd like to hear your suggestions for future columns. You can contact me at P.O. Box 1099, Falls Church, Virginia 22041.

references

1. *Handbook for the Radio Amateur*, 1987 Edition, American Radio Relay League, 225 Main Street, Newington, Connecticut 06111. 1988 edition available from *ham radio's* Book Store, Greenville, New Hampshire 03048; $20.95 (hardbound), plus $3.50 shipping and handling.
2. Joe Reisert, W1JR, "Broadband Amplifiers in Receiver Design," VHF/UHF World, *ham radio*, November 1986.
3. Michael E. Gruchalla, "NE5205 Wideband rf Amplifier," *ham radio*, September 1985.
4. Michael E. Gruchalla, "Build Your Own 'Audio to Microwave' Amplifier," *ham radio*, March 1984.

ham radio

the technology of
commercial television
part 1: historical aspects

Ever wondered how it works? Take this ham's-eye tour of a commercial tv station

A television station contains more different types of electronics in one location than any other enterprise I can think of. Yet in the 20 or so years that I've been reading the literature of Amateur and commercial electronics, I've never seen a comprehensive account of the technical aspects of a commercial television station. I won't pretend that the system we use here in the United States is perfect, but I do believe it represents both the systematic evolution and the efficient use of available technology — and as such, merits attention in the Amateur press.

what is NTSC?

Most video hobbyists have seen the initials *NTSC* and assumed that it meant "Never The Same Color." Although this aptly describes the American television system when compared with more advanced systems, the acronym actually stands for "National Television Standard Committee," who developed and defined the way a television system should work in 1953. Believe it or not, there haven't been any changes in the NTSC standards since their adoption, even though the technology for creating these NTSC television signals has obviously changed radically.

why NTSC?

To explain how a standard such as NTSC, or any other standard, is derived, we must deal with a concept fundamental to all communications: bandwidth, or the range of frequencies necessary to convey a given amount of information. Leaving aside any mathematical definitions of bandwidth, I'll attempt to convey the idea in English instead.

An example of a narrow bandwidth system would be the telephone. To convey speech information by telephone, we need a range of frequencies between about 300 and 3000 cycles per second (Hz). The audio bandwidth in this case is 3000 − 300, or 2700 Hz. When the telephone mouthpiece converts the sound to electrical signals, we still have a bandwidth of 2700 Hz.

High fidelity audio, on the other hand, is an example of a greater (wider) bandwidth. Most audiophiles agree that we need a frequency range of at least 20 to 20,000 Hz in order for sound to qualify as high fidelity, or a bandwidth of 20,000 − 20 (19,980 Hz). Our entire system must be capable of passing electrical signals over a bandwidth of 19,980 Hz in this case.

When we convert visual images to electrical impulses, we also have to deal with bandwidth. Normal video has

By Eric Nichols, KL7AJ, Box 0, North Pole, Alaska 99705

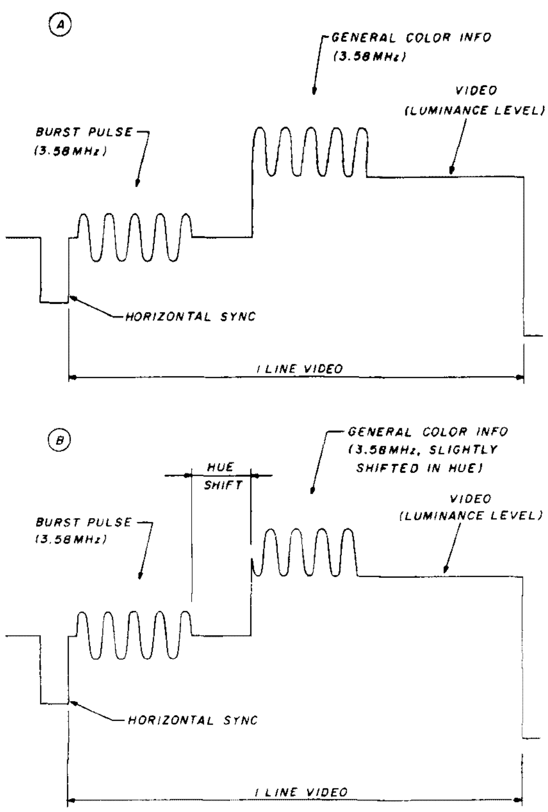


fig. 1. Burst pulse timing.

a frequency range of 0 Hz (dc) to about 4,180,000 Hz, or a 4.18-MHz bandwidth. This is over 200 times the bandwidth required for high fidelity audio, and over 1500 times the bandwidth required for a telephone (voice grade) circuit!

If we were to define a channel as being a slot of frequencies 2700 Hz wide, we'd see that a video picture will use up over 1500 channels! Now, as long as our raw video or audio electrical signals are confined to electrical conductors (i.e., in a closed-circuit system), we don't have to worry (theoretically, at least) about how many channels we occupy. We can duplicate identical channels on separate wires. In other words, the amount of information we carry is limited only by how many audio or video cables we want to run. High-definition television (HDTV), for example, has been available for quite some time on closed-circuit systems, and its bandwidth is several times greater than the NTSC-specified 4.18 MHz.

When we take these same channels and transmit them over the air, every channel of radio spectrum we use must be shared with the entire universe. Radio waves, of course, recognize no geographical, political, economic, religious, or psychological boundaries; herein lies the necessity for making compromises in bandwidth, and NTSC is the system by which a very good compromise is made with available channel space.

When the NTSC color sytem was developed, there were already over 40 million monochrome television receivers in operation in the United States! The NTSC's first job, therefore, was to make a color system that would work on black and white receivers; after all, 40 million households could not be expected to take lightly the prospect of having their extremely expensive (at the time) receivers being rendered obsolete by a new television standard! This is one price the United States paid for being first; most of Europe waited for us to develop color television before they had any television, so that they wouldn't have to contend with a compatibility problem. Great Britain and a few other nations still flounder with awkward dual-standard systems (i.e., separate color and monochrome channels).

And yes, France's SECAM system has more than twice the visual resolution as ours, but they have fewer than half the available channels. Their channels are as broad as a barn door, and no other nation can afford to wipe out that much spectrum space, nor can many people afford the receivers.

As numerous as the problems are with the NTSC system, we still have the most uniform and affordable television system in the world, one that is reasonably conservative of spectrum space. The fact that the NTSC system is still widely imitated in much of the world testifies to the foresight and ingenuity of the developers of the NTSC standard.

Given the importance of spectrum conservation, we now see that NTSC had to compromise in the least objectionable fashion, i.e., in the way that would impair image quality as little as possible. A color television signal obviously contains more information than a black and white signal, and since more information requires greater bandwidth, something has to give when you try to force a color signal into a video channel. NTSC discovered gaps in the brightness information in average video program material — in fact, they found almost no video information occurring at about 3.5 MHz in a normal monochrome signal. Subjective tests with thousands of untrained viewers revealed that when a narrow band of frequencies centered near 3.5 MHz was intentionally filtered out, nobody noticed. Color information, therefore, could be slipped into this segment without affecting the perceived quality of the final image.

The NTSC system was television's earliest and best example of what we now call "ergonomic" or human engineering. Every aspect of the new NTSC system was checked for its subjective perceived qualities; even the choice of color phosphors was determined by evaluating the responses of viewers.

everything but the kitchen sync

Before we can have a quality image, we must have an image — and without synchronization or "sync," as it's usually called, we have no image. It's common knowledge that a television image is created by scanning an electron beam back and forth across a phosphor screen. Few viewers realize, however, just how tight the tolerances relevant to the positioning of that beam must be, particularly with color television. It's the sync system that controls these tolerances; in fact, most of a television transmitter's power is devoted to generating sync pulses so that we can have a stable scan or raster. This will be covered in detail next month, when we discuss transmission techniques.

Typical movie theater projectors display 24 frames per second, but the NTSC system specifies 30 complete frames per second. Unlike movie frames, each video frame consists of two interlaced fields. NTSC scans 525 lines per field, but not adjacently; instead, a field of 262-1/2 lines is scanned, with the odd lines "filled in" during the next field. Even experienced television service tecnhicians are sometimes surprised to learn about this interlace scheme; some are amazed that a television works at all when they realize what's required to achieve accurate interlacing. This interlace achieves two things: first, it reduces flicker to the same level as would be sensed at 60 frames per second without increasing the bandwidth. Second, by flipping the color polarity of the odd lines upside down, the color information "disappears" from monochrome receivers. We use 60 fields per second rather than 53, 65, or 80.4 because in the United States, ac power is 60 Hz, and the ac power is convenient for achieving approximate control of the frame lock (vertical hold).

Another critical element of image quality is synchronization of the horizontal sweep. This means that the left-to-right positioning of the receiver's scanning beam has to correspond exactly with the scanning beam of the studio camera. So before each scan (video line), a horizontal sync pulse is transmitted at a repetition rate of 15,750 Hz or:

30 frames/second $\times$ 525 lines/frame =
15,750 lines/second)

This is the annoying frequency you sometimes hear emanating from television sets; all the high-voltage circuitry resonates at this frequency.

color

I mentioned earlier that in a normal monochrome signal, almost no video information occurs at approximately 3.5 MHz. Actually the FCC states that the color information must be centered at 3.579 MHz. For general purposes, the FCC refers to this as 3.579545 MHz; for convenience, broadcast engineers refer to it as simply 3.58 MHz. The greater precision is justified, however,

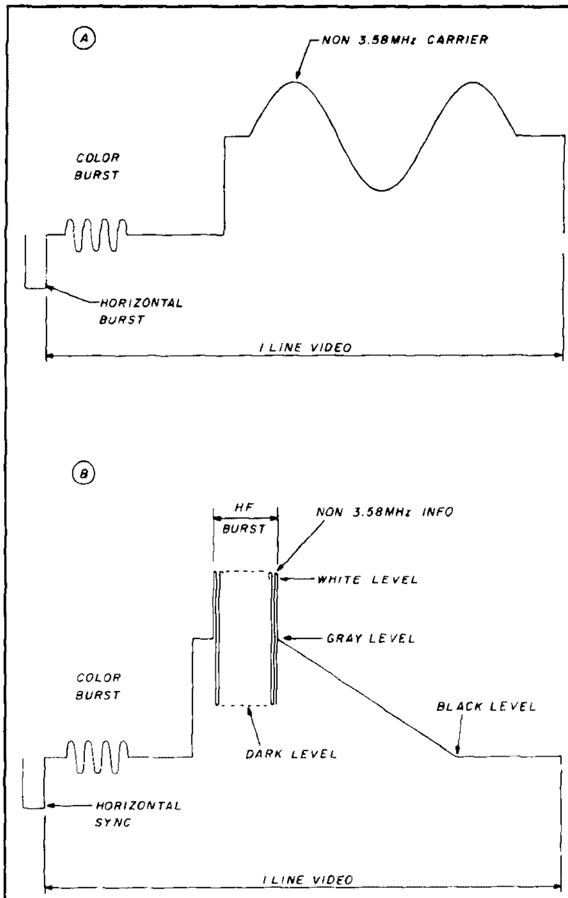


fig. 2. (A) Modulation of the video level not at the color frequency; (B) this pattern tests the resolution capabilities of the system.

in that the subcarrier can be locked to the National Bureau of Standards' 5-MHz transmission. The 3.58-MHz color subcarrier is the most accurate reference to which the average citizen has access; in fact, many scientific and navigational firms use the color reference from a local television station as a time reference. (For accuracy, the television station must be locked to a satellite network.)

So what do we do to this 3.58 MHz to give us color?

We can change three things about any electrical wave: its height (a-m), its frequency (fm), or its timing or position relative to a fixed reference wave of the same frequency (phase modulation). Two of these — a-m and phase modulation — are done to the color subcarrier. (Fm is obviously out of the question.)

Changing the amplitude of the wave changes the saturation of the color at that particular period of time. Saturation is what you change when you tweak the "color" control on your television set. Changing the phase or timing of that carrier at that point in the scan

changes the "tint" or "hue." In other words, the phasing tells the receiver which color to present at that spot on the screen.

The horizontal sync pulse comes just before the color burst. The burst is about 10 cycles of 3.58-Mhz signal at the beginning of each and every line. Its phase, compared to every other burst, is absolutely constant. But after the burst, the information changes according to the color we want. **Figure 1** shows two lines of video that are identical except that the phasing of Genuine Color Information in B is shifted slightly from that of A. (How a receiver compares such a subtle thing as a phase shift will be addressed next month.) In reality, unless you're actually looking at a solid white background, the video line will be wavy all the way across. **Figure 1** shows modulation only at the color frequency.

Figure 2A shows modulation of the video level, not at the color frequency. This will have no effect on the color because it's not 3.58 MHz; instead, it will appear as a gradual increase from gray to white, down through gray toward black, up through gray toward white, then down to gray again. Keep in mind that this is just a single line of video repeated 15,750 times each second.

the 3.58-MHz tie

Figure 2B is very interesting. The section labeled "hf burst" represents what would happen if the camera looked at a very fine black and white pinstripe pattern. Because the video modulation is higher in frequency than color, once again no color appears. This pattern tests the resolution capabilities of the system. In other words, some herringbone suits are very high-frequency suits; such a suit will increase in frequency as the camera backs off or "zooms out." So if you're going to be on television, be sure to select your clothes with regard to frequency response. Once in a while, someone will wear a 3.58-MHz tie that displays rainbow patterns on less-than-perfect color televisions. When this happens, the only solution is to change the tie's frequency by zooming in or out.

After the hf burst, the video goes into a "ramp," a gradual fade from medium gray to black.

from studio to receiver

So far, we've spoken mostly of the raw video; in other words, we haven't considered what happens to the video between the studio and the receiver. We did mention that the radio signal path is a limited bandwidth channel, and that the NTSC signal is tailored accordingly. But what does the signal look like after it leaves the transmitter?

The visual portion of a television signal is a modified form of a-m. Television falls in an area between a-m and single sideband called Vestigial Sideband (VSB). A standard a-m transmitter emits a channel which is twice the bandwidth of the modulating signal. It doesn't matter what form the modulation takes; if we take a 4.18-MHz wide video signal and put it into an a-m transmitter, our transmitted signal will occupy 8.36 MHz of precious spectrum space.

The emitted channel consists of two sidebands, symmetrically spaced on either side of the carrier frequency. One sideband is redundant; each carries the same information except that one is inverted in frequency — a mirror image, so to speak. The carrier frequency of Channel 2 is around 55 MHz; the carrier frequency of Channel 13 is around 211 MHz. (In every case, the television audio carrier is 4.5 MHz above the visual carrier, but we'll discuss that later.)

Because one sideband is redundant, we could lop off either one and still have a complete video signal. In SSB radio, we do exactly that, and thus end up with a radio frequency channel of exactly the same bandwidth as our audio modulation channel.

In television, we remove most of the lower sideband, leaving the upper sideband intact. The only reason we don't completely eliminate the lower sideband is attributable to technical considerations which no longer apply, but since the rules were cast in concrete 35 years ago, it looks like we're stuck with VSB for the foreseeable future. However, the NTSC made a noble step in the right direction when they opted for VSB instead of full a-m.

Unlike SSB radio — where it's easy to regenerate the carrier upon reception — in television we leave the carrier untouched because eliminating it would make receiver design hideously complicated. Although our transmitters would be more efficient if we could eliminate it, the carrier doesn't occupy any spectrum space and is therefore of no concern.

Figures 3A and **3B** compare the occupied bandwidth of a-m to VSB. What do we put where the LSB used to be? The upper part of the next lower television channel, of course. It would be nice to leave that lower sideband gap as elbow room, wouldn't it? Unfortunately, both nature and the FCC abhor a vacuum, and one or the other guarantees that something is going to be there. In most cases, it's a television station, unless you happen to be talking about channel 7, in which case it happens to be the fm broadcast band as well as most high-band VHF fm communications.

Actually, the lack of elbow room between television stations would never create problems in properly designed television receivers. Unfortunately, nobody makes any. Even though the quality of the video sections of television receivers has improved dramatically in the last three decades, the radio frequency sections, or front ends, have gotten worse. The old tube receivers of the 1950s had far better selectivity than any receivers built now.

(continued on page 65)

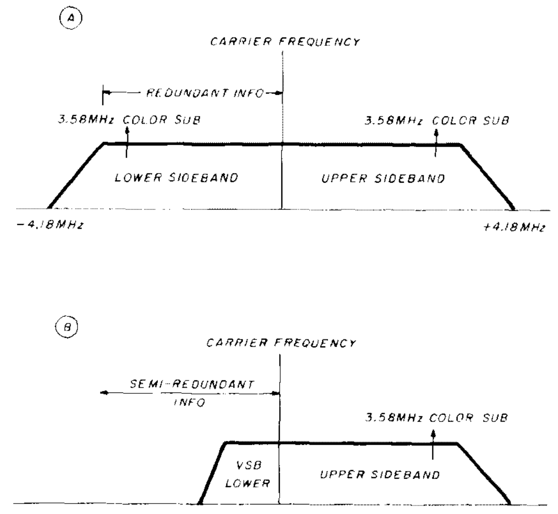


fig. 3. (A) TV visual spectrum (full a-m); (B) TV visual spectrum (VSB).

Referring back to **fig. 1** and **2**, it should be mentioned that these are upside down as far as transmitted power is concerned. In other words, even though the sync pulse is shown at the bottom, it's actually maximum transmitted power and modulation. As a matter of fact, transmitters for television are licensed according to peak power, or sync peak envelope power. There are several good reasons for this practice: first, the sync represents a constant value, which is reasonably simple to measure or calculate. The FCC requires broadcasters to know how much power they're radiating. Because the video waveform is continually changing, it would be practically impossible to represent power output in terms of "average picture modulation" or some other such nebulous term. By putting the sync at the top, in terms of power, we at least have a maximum power measurement. (In "real" television, we never have a condition of unmodulated carrier as we do in radio, so we can't talk about a television station's licensed carrier power.) The second reason for having the sync at the top relates to our original discussion of sync pulses. We mentioned that there's no point in having a nice-looking video image if it isn't stable. By placing the sync pulses at maximum output power, we ensure that as the received signal gets weaker, the last thing to go will be picture stability. This one characteristic, common to television standards around the world, allows us to have a usable picture under much poorer conditions than would be acceptable if the sync pulse were at a lower transmitter modulation.

One thing that does vary from standard to standard is in what direction you go to get from black to white. In NTSC, the blacker you go, the closer you get to sync power. In the British system and others, white is transmitted near sync level and black is at lower modulation levels. A British picture viewed on NTSC, therefore, would appear as a negative rather than as a positive image.

Each polarity of video offers certain advantages. The NTSC system has a better signal-to-noise ratio in the black region, which translates into less visible "snow" in the darker areas. On the other hand, it's generally easier to achieve linearity on most types of transmitters with the inverted video systems. (Linearity, in this context, refers to the degree of video "fidelity.") A more linear system reproduces luminence levels, or shades of gray, more accurately.

waveform monitor

The waveform monitor (**fig. 4**) — a vital piece of test equipment common to all television stations — is a specialized form of oscilloscope used to view video signals either line by line or field by field. Actually, any good oscilloscope would be sufficient.

Although many different graticules are used, the IRE is by far the most common. Note that the graticule has two scales. The left scale represents IRE units. The IRE scale of 140 units is divided into 100 units of genuine video information and 40 units of sync. The 0 division or baseline is clamped at 0 volts in most television stations. In other words, anything below 0 is a negative voltage, while anything above 0 is a positive voltage. The right side of the scale indicates the percentage of modulation of an actual television transmitter, assuming everything is working satisfactorily.

I've shown one line of a "window" signal superimposed on the graticule; this appears as a white left half and a very black right half of the screen — television screen, that is; waveform monitor screens are green. Notice that sync is 100 percent modulation, the baseline is 75 percent modulation, and pure white is 12.5 percent modulation. Why isn't white set at 0 percent modulation? Because television receivers need a little bit of visual carrier (12.5 percent) to demodulate the audio signal. Did you ever notice that raspy buzz in the audio when a television station runs credits or other very white characters? This is what happens when the video accidentally gets past 12.5 percent white towards 0. Television receivers use a technique called intercarrier sound demodulation to simplify the receiver tuning circuitry. It's a system I'd get rid of if I were Emperor, but that's unlikely to happen.

The IRE scale is quite convenient for visual quality control. As long as we keep our visual range between 0 and 100 units on the left, we'll have a reasonably pleasant-looking picture. In practice, genuine video information (GVI) should never go below 7.5 IRE units. This tiny setup level prevents our GVI from confusing our

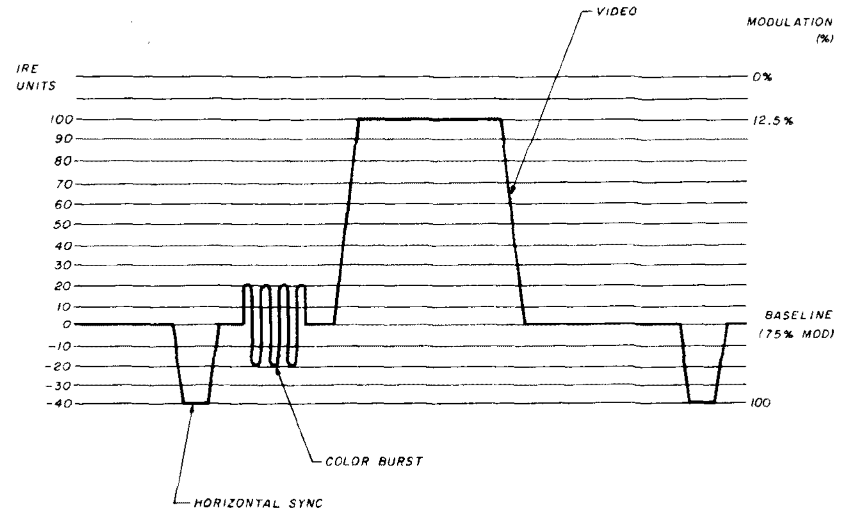


fig. 4. Modulation as expressed in IRE units on graticle of a waveform monitor.

baseline clamping circuitry. We'll talk more about clamping next month, but for now, let's just say that clamping is there so that television sets know where black ends and sync begins.

television sound

Although the NTSC had little to do with the the development of television audio, television transmitters have always been capable of excellent audio. In fact, the audio section and legal FCC specifications for television audio are essentially identical to those specified for fm radio! Television frequency response uses exactly the same 75-ms pre-emphasis curve as fm broadcasting, for example, and the total harmonic distortion specifications are the same as those for fm radio (monaural).

So why has television audio — until very recently — sounded so poor? There are two weak links in the television audio chain: the first is in production techniques. In most videotaped and live television fare, audio has generally been added on almost as an afterthought. Quality audio has nothing to do with technology; it's simply a matter of quality control and care. The second weak link has been intercarrier sound demodulation, mentioned briefly above. The intercarrier technique is extremely clever, but that's about all I can say for it; too many compromises in overall audio quality are required, so the purpose of transmitting good audio is almost defeated. Intercarrier sound demodulation has greatly complicated the problem of stereo audio transmission, but even so, it seems like it's here to stay.

Visitors to television stations are often amazed by how good the audio sounds. This is because a television audio "modulation monitor" is a discrete (i.e., non-intercarrier) tuner and because the monitors in the control room usually use full-size, full-range speakers. So all is not lost when it comes to television audio, and more and more producers — especially with increasing public interest in stereo reception — are beginning to pay some attention to audio techniques and quality control.

The unmodulated sound carrier is exactly 4.5 MHz above the visual carrier. It is frequency modulated ±25 kHz under maximum loudness from this carrier. The modulation of an fm carrier results in the generation of some sidebands which overlap into the video portion of the channel. For this reason, most television receivers have a "sound trap" that notches the audio out of the video chain. In general, though, this slopover has minimal detrimental effects on the video, and some high-resolution monitors do not include sound traps.

As far as aural (audio) carrier power is concerned, a typical television station cranks out only one-fifth as much aural power as peak sync power. The reason for this has to do with the bandwidth of the aural compared to the bandwidth of the visual system. A narrowband system, of course, needs less power to do the same job as a wideband channel.

tune in next month . . .

In the next installment, I'll describe station equipment that processes signals ranging from dc through visible light. Topics covered will include antennas; mechanical, electrical, and audio devices; light transducers; analog and digital electronics; rf and microwave devices; power generation and distribution; wave propagation; and just a tiny bit of nuclear physics.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

low-noise receiver update: part 2

In last month's column,[1] in which we discussed the state of the art (SOA) in low-noise receivers and preamplifiers, I pointed out that some incredibly low noise figures are now possible using very affordable (less than $10) GaAsFETs. HEMTs (high electron mobility transistors), the latest rage, can cut noise figures by as much as 50 percent; though HEMT prices are pretty steep right now, they are dropping.

Last month's column also discussed ways to decrease noise figure by proper component selection and cooling techniques. This month's column will be more practical, stressing recommended circuitry, stability techniques, and device selection. We'll review testing and talk about improvements that can be expected in the near future.

recommended circuits

By now you're probably wondering what circuitry to use for GaAsFET preamplifiers. Reference 2 discussed recommended circuits for 144, 220, and 432 MHz. Those circuits still are close to optimum for a simple competitive preamplifier without any special components or tricky techniques.

Reference 3 showed a recommended preamplifier for 903 MHz. Simple to construct and align, it had a noise figure of approximately 0.5 dB when an appropriate GaAsFET was used.

Techniques improve with time. Therefore, before recommending a final circuit, let's first review the major considerations in selecting the individual components and circuit topology.

input circuits

Last month we discussed recommended input-matching circuits for GaAsFET VHF and lower UHF region preamplifiers. We emphasized that one of the most practical input-matching circuits is still the step-up resonant transformer with a capacitor tap.[4] This configuration has low insertion loss, a wide adjustment range, and provides *reasonable out-of-band rf signal rejection.*

Reference 1 also stressed that most of the noise figure in today's typical Amateur preamplifiers is caused by losses in the input impedance matching network. Use only components with the highest possible unloaded *Q*. Cavity-type construction may be required, especially if noise figures of less than 0.5 dB are required on 432 MHz and above. However, that is beyond the scope of this month's column.

output circuits

There are many types of output-*matching circuits used in Amateur* GaAsFET preamplifiers. Some of them are shown in **fig. 1**. It is desirable when selecting the output circuit to make sure that it has sufficient bandwidth so that it doesn't become the bandwidth-limiting device in the preamplifier.

An output tank circuit similar to the one recommended for input matching is shown in **fig. 1A**. *It is definitely not recommended and should be avoided* for a number of reasons: first, because it will usually increase the gain well above the desired operating level, 15 to 20 dB, as discussed in reference 1; second, because it's very difficult to decouple a high-impedance output tank circuit from an input circuit sufficiently, thus creating a source of feedback and potential oscillations; and third, because the reflected impedance of the following amplifier stage on the tuning of this output circuit may cause

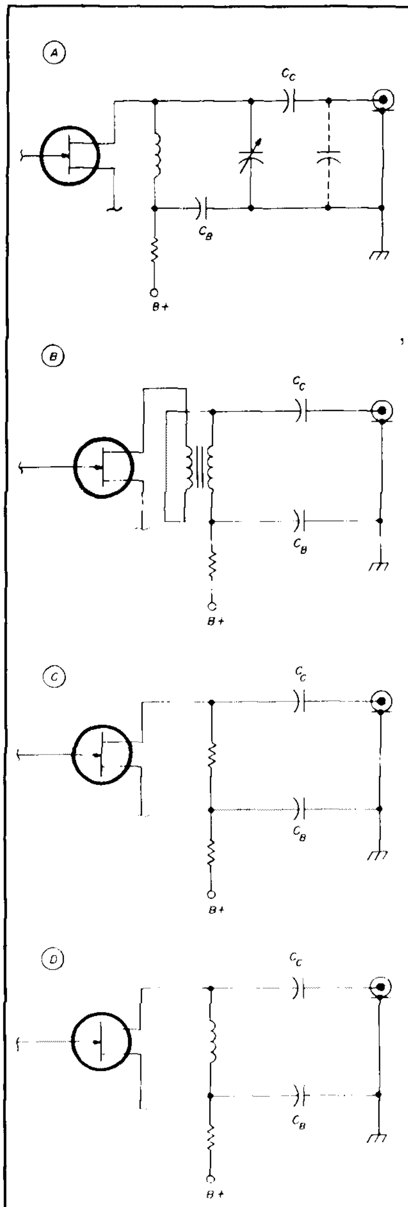


fig. 1. Typical GaAsFET output-matching techniques. C_B is an rf bypass capacitor; C_C is the coupling capacitor as described in the text. (A) shows a tuned tank circuit (not recommended); (B), a bifilar wound 4:1 transformer; (C), resistive loading; and (D), an L-network.

additional instability when the preamplifier is placed in your system.

The bifilar-wound output transformer (**fig. 1B**), first proposed for GaAsFET preamplifiers by Bob Sutherland, W6PO, has stood the test of time. It's easy to construct and works well up through 432 MHz.[5]

Resistive loading, shown in **fig. 1C**, has been used in the past, particularly where gain is very high.[6] It certainly calms down hot high-gain devices, but will also lower the output power and the dynamic range of a preamplifier.

In reference 3 I introduced a simple form of L-network that effectively replaces the bifilar type of transformer matching (**fig. 1D**). It's not only easier to build, but also provides some selectivity. Furthermore, it typically yields slightly higher gain and output power (at the 1-dB compression point) than the bifilar transformer.

Table 1. Typical GaAsFETs popular with Amateurs

Type	Noise figure at frequency (GHz)	Approximate price	Notes
AT 8110	1.1 dB typical at 4	$27.00	
ATF 10135	0.5 dB typical at 4 1.8 dB typical at 12	$10.85	
CFY 19	1.8 dB maximum at 6		low cost
MGF 1100	2.5 dB typical at 4	$7.50	
MGF 1202	2.0 dB maximum at 4	$10.00	discontined use MGF 1302
MGF 1302	1.4 dB maximum at 4	$10.00	replaces MGF 1202
MGF 1402/2SK274	1.4 dB maximum at 4	$14.00	replaces MGF 1202
MGF 1412/2SK275	0.8 dB typical at 4 1.7 dB typical at 8	$26.00	
MRF 966	1.2 dB typical at 1	$2.00	dual-gate
NE 202	1.0 dB typical at 12		HEMT
NE 04583	0.8 dB typical at 8 1.5 dB typical at 12		
NE 41137	1.3 dB typical at 0.9	$3.00	dual-gate
NE 72084/2SK571	0.6 dB typical at 2 1.4 dB maximum at 4	$10.00	replaces MGF 1402

final circuit

Figure 2A shows a recommended GaAsFET preamplifier circuit for the 144, 220, 432, and 903-MHz Amateur bands. It uses a capacitance-coupled input tank circuit as described in reference 1. The output circuit is an L-network as just described. Note that the capacitance of the output coupling capacitor is much lower than typically seen in other GaAsFET preamplifiers.

Source biasing is used because it's simple, effective, and requires only a single power supply. The drain voltage is supplied from an inexpensive three-terminal voltage regulator through a limiting resistor. This provides simple protection to the GaAsFET.[7] The zener diode, CR1, is simply used for overvoltage protection and will be described shortly.

Note that a ferrite bead is placed on the drain lead. At the frequency of interest it dissipates only 0.5 to 1.0 dB of the preamplifier gain. However, in the microwave region where most GaAsFETs still have plenty of gain, it prevents undesirable oscillations.

component selection

Before building a preamplifier, you should first consider which components are to be used. The GaAsFET choice is important, but don't get carried away by using one that is specified well above your operating frequency, because you may end up with a higher noise figure than expected at a price that isn't cost effective.[1]

It's best to choose a GaAsFET that's specified at or just above your band of interest. Many GaAsFETs are now available, especially some that were popular several years ago but are now obsolete by today's standards. Most will operate in the circuit shown in **fig. 2** with only slight differences in tuning. Dual-gate GaAsFETs can also be used in this circuit if the second gate is biased as shown in **fig. 2B**.

Table 1 has been prepared to assist you in GaAsFET selection. Several devices, mostly those that are popular with Amateurs, are listed. While there are many GaAsFET manufacturers, most semiconductor suppliers don't like to deal with individuals except through distributors (for instance, Avantek and Motorola) or unless a large order (typically greater than $50) is placed. Fortunately, at least two Amateur suppliers can help — not only with GaAsFETs, but with some of the hard-to-find components.*,**

As described in reference 1, the input-matching capacitors should have a very high unloaded *Q*; the Johanson or equivalent air variables are appropriate. Likewise, the inductors described in the component list are close to optimum for unloaded *Q*. Always use large-diameter (No. 14 AWG or larger) copper or copper-plated wire. Keep inductors away from nearby objects because they can cause the unloaded *Q* to decrease.

Low insertion loss connectors with good impedance characteristics are desirable at the preamplifier input. Type N, SMA, or TNC are recommended. However, less expensive connectors can be used for the preamplifier output connector when losses aren't a great concern.

The capacitive values of the source bypasses aren't critical, but they should be chip or leadless ceramic or porcelain types. Suitable inexpensive types are available from Michigan Microwave.** The rest of the components don't require further explanation. The type of enclosure to be used will be described shortly.

* Norm Alred, WA8EUU, Microwave Components of Michigan, 11216 Cape Cod, Taylor, Michigan 48180.

** Steve Kostro, N2CEI, R.D. 1, Box 341A, Frenchtown, New Jersey 08825.

construction techniques

Just like other low-noise circuitry, GaAsFET preamplifiers require good construction practices if optimum performance is to be achieved. Poor construction will result in mediocre performance indicated by low gain, moderate to high noise figure, and instability — or all of the above.

Choose a shielded enclosure. I prefer cast aluminum boxes such as the Bud model CU123 or CU124, the Hammond 1590A or 1590B, or equivalent. Attach a piece of ordinary double-sided printed circuit board to the cover of the enclosure as shown in **fig. 3A**; it can be held in place by the input-output connectors and the input power connections.

Figure 3 can be used as a guide to recommended component location for a GaAsFET preamplifier. **Figure 3A** is a top view of the subchassis; **fig. 3B** shows the side view. In particular, note the position of J1, C1, C2, and L1, since their location and proximity to each other help keep input losses (as well as noise figure) low. The raised bracket shown in **fig. 3C** is used to mount the GaAsFET at the proper height so it can be connected directly to the matching network using only its gate lead. At the same time, the leadless or chip capacitors can be easily attached to this bracket.

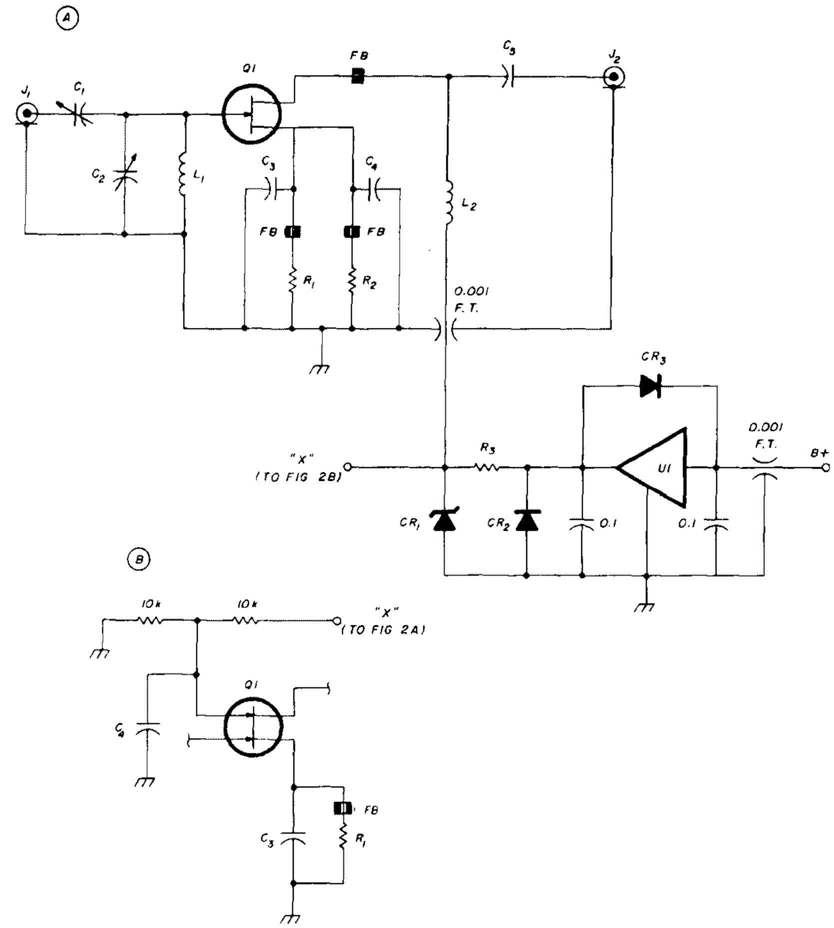


fig. 2. Schematic of a recommended GaAsFET preamplifier for use on 144 through 903 MHz: (A) typical single-gate GaAsFET with two source leads; (B) a modification to fig. 2A to accommodate a dual-gate GaAsFET.

stability considerations

Like bipolar transistors, GaAsFETs can be very unstable if they're used improperly. Poor circuit performance can be traced to rf as well as dc instability or both!

When GaAsFETs first appeared on the Amateur scene, dc stability was a real problem. Negative gate biasing was often used, and when it failed (which seemed to be quite often), the expensive GaAsFETs died a quick death. Nowadays, most Amateur circuits use source biasing as shown in **fig. 2**. This way, the drain current of the device is automatically limited.

If source biasing is used, rf bypassing can be a problem. Always use bypass capacitors that have little or no series inductance such as the chip type. The actual capacitance value isn't important as long as the capacitive reactance is below 1 or 2 ohms at the operating frequency.

A ferrite bead on the drain lead will help eliminate rf instability in the microwave region, as mentioned previously. Likewise, a ferrite bead on the leads of any resistors or chokes (if used) in the rf path is recommended. I've seen some preamplifiers that have a diplexer incorporated on the output of the preamplifier using a parallel resonant circuit and a 50-ohm resistor.[7]

Sometimes the enclosure can be a problem, since it may act like a waveguide — but the lower the height of the enclosure, the less likely the problem is to occur. Proper component layout is, of course, recommended. Shields between the input and output circuits are also suggested. I've seen some commerical suppliers add ferrite absorbers inside an enclosure as a last resort.

GaAsFET preamplifiers have moderately high input and output impedances and usually don't have much isolation between the input and output circuits. Remember that GaAsFETs are like the old triode vacuum tubes that were often neutralized (ugh!). For circuit stability, they rely on a low capacitance between the gate and drain, and on keeping the gain at a reasonable level.

Most Amateurs tune up their preamplifiers in a well-matched environ-

ment with a good (low VSWR) input and output load. Then, when everything looks great, they often insert the preamplifier into a system that's matched at the frequency of operation but highly reactive out of band. If the gain is too high, if the loading of the following stage is the wrong impedance or phase, or if the reverse isolation of the preamplifier is inadequate (more on this shortly), the preamplifier may become unstable and "take off and fly."

For the reasons stated above, many commerical suppliers follow their preamplifiers with a ferrite isolator or circulator which effectively presents a good output impedance match irrespective of the load. This is great, but the cost of such a device is often more than the price of the typical Amateur GaAsFET preamplifier alone! Needless to say, beware of potential instabilities.

modifications to existing preamplifiers

Often I'm asked if the commercial Amateur GaAsFET preamplifiers can be modified or improved. The answer is usually yes — if there's sufficient room to work within the enclosure.

I recently had one of the 70-cm (432 MHz) EMEers send me his very low noise GaAsFET preamplifier. It worked fine on his bench, but oscillated when it was inserted in his EME system. I tested the circuit and found that it indeed had a good noise figure in a well-matched environment such as the one described above. However, when I looked at the circuit, I was shocked; there was the typical tuned output tank circuit that I lambasted earlier (see **fig. 1A**)!

I carefully removed the inductor and all the tuning capacitors in the output circuit and replaced them with a simple bifilar-wound transformer (**fig. 1B**) and a dc blocking capacitor.[1] Sure enough, the gain dropped slightly (which is of no consequence, since it was already too high) and stability returned. There was no measurable change in noise figure. Another distressed preamplifier was rescued.

Often a new, lower noise figure GaAsFET can be substituted in an existing preamplifier. I'm sure there are other instances when minor circuit changes can be made to an existing preamplifier following the guidelines in this month's column. After all, who cares if a preamplifier has close to a 0.0-dB noise figure if it won't work in a realistic environment? Jump in and rescue it rather than letting it rest unused in your desk drawer.

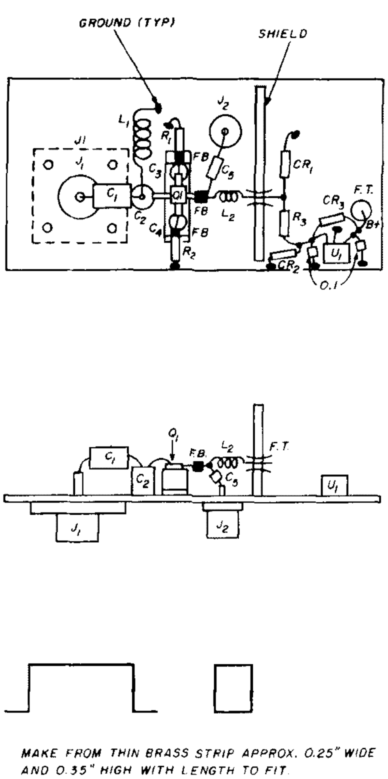


fig. 3. Recommended construction techniques for a GaAsFET preamplifier used on 144 through 903 MHz: (A) looking down on component side; (B) side view. For clarity, some components are not shown. (C) shows grounding pedestal for GaAsFET.

GaAsFET destruction

I still hear horror stories about GaAsFETs that get destroyed. These cases usually involve mast-mounted preamplifiers. More often than not, the problems are caused by poor antenna change over relays or lack of relay sequencing.

Most modern low-noise solid-state devices are moderately reliable and can usually withstand low levels of rf (100 milliwatts, +20 dBm, or less) for at least a few milliseconds, the typical switching speed of a normal T/R relay. However, for best reliability and continued low noise figures, rf levels should be kept at least 10 dB lower — not to exceed 10 milliwatts (+10 dBm).

Many of the commonly available T/R relays used by Amateurs have only 30 to 40 dB of receiver isolation on 144 MHz, with 25 to 30 dB typical at 432 MHz. With 500 watts (+57 dBm) of power and 30 dB of isolation, the leak-through power on the input of the preamplifier would be 0.5 watts (+27 dBM), high enough to blow out even a stiff transistor!

parts list

C1,C2	0.5 to 10 pF low-loss air variable (see text)
C3,C4	leadless or chip bypass capacitor, 470-1000 pF (see text).
C5	144 MHz: 6.8-7.5 pF
	220 MHz: 4.7-5 pF
	432 MHz: 3.9 pF
	903 MHz: 3.0 pF
CR1	5.6 volt zener, 1N751 or equivalent
CR2,CR3	1N4001 or equivalent silicon diode
FB	Ferrite bead, Type 3B, 4A, 43, or equivalent
J1	Low-loss input connector, N, SMA or TNC preferred.
J2	Output connector. Type not critical.
L1	144 MHz: 5 turns No. 14 on 3/8-inch ID, 0.5 inch long.
	220 MHz: 5 turns No. 14 on 0.25-inch ID, 0.5 inch long.
	432 MHz: 1 turn No. 14 on 0.32-inch ID. Length of wire 2 inches overall.
	903 MHz: thin (0.02-03 inch) copper strap 1.0 inch long overall.
L2	144 MHz: 10 turns No. 24 on 0.1-inch ID, 0.25 inch wide and 0.5 inch long.
	220 MHz: 8 turns of No. 24 on 0.1-inch ID, 0.5 inch long.
	432 MHz: 5 turns of No. 24 on 0.1-inch ID, 0.5 inch long.
	903 MHz: 3 turns of No. 24 on 0.1-inch ID, 0.25 inch long.
Q1	See text and table 1
R1,R2	200 ohms typical. Select for I_D of 7-10 μA (see text).
R3	100 ohms typical (see text).
U1	5.0-volt, three-terminal voltage regulator, 78L05 or equivalent.

You can best limit the rf level on the input of your preamplifier by use of a high isolation relay, typically 50 dB. Better yet, use a dual relay system like the one suggested in references 8 or 9. The second relay can be a low-cost type and will significantly increase relay isolation. Furthermore, on transmit, the preamplifier can be returned to a 50-ohm load, thus preventing any tendency towards oscillation and possible destruction.

As described in references 8 or 9, relay sequencing is highly recommended. Chip Angle, N6CA, has proposed a more sophisticated sequencing scheme built around a quad operational amplifier.[10] It provides several different delay times for switching receivers, exciters, and transmitters and is suggested for extra protection.

Don't overlook the dc biasing conditions just discussed. Source biasing and voltage-regulated power supplies will help GaAsFETs. Remember also that dc spikes are another potential problem. That is why I've always recommended the use of three-terminal voltage regulators with zener diode over-voltage protection as shown in **fig. 2**.

Sometimes I see Amateur preamplifiers with a spike-protection zener diode shunted between the drain and source. If you use this technique, don't forget to use ferrite beads in series with the diode, since it's in shunt with the rf path and could introduce rf feedback.

As I've recommended many times before, provide a dedicated power supply for your low-noise preamplifier and a separate dedicated supply for all relays. Inductive spikes from switching relays can kill any low-voltage unprotected device operating on the same voltage line! If only one supply is used, provide spike-limiting diodes on the relays, as recommended in reference 9.

Another sporadic problem is handling GaAsFETs while inserting or soldering them into circuits. Always use a low-power soldering iron with the tip grounded to the chassis. Also, first ground yourself to the chassis or use a "wrist strap" before contacting a GaAsFET. Static *kills* GaAsFETs!

Finally, beware of rf and static discharges such as lightning. The best protection is simply removing your preamplifier from the system when it's not in use. Input filtering will go a long way towards protection of a low-noise preamplifier. In this regard, the capacitance-coupled input circuit shown in **fig. 2** is highly recommended.

TVRO LNAs

The TVRO (TV receive only) LNAs (low-noise amplifiers) are literally everywhere, now that much of satellite TV is scrambled. I've seen them for sale at flea markets for less than $30! Typically, they have 50 dB of gain specified for operation from 3.7 to 4.2 GHz and use two or three stages of GaAsFETs followed by three to four stages of bipolar transistors.

TVRO LNAs are usually great "as is" for operation on 3456 MHz, and will typically have a 1.5-dB noise figure in the Amateur band. Dave Mascaro, WA3JUF, recently described not only how to use them as receiver preamplifiers, but also how to modify them for use as low-level transmitter amplifiers.[1]

They're also a great source of spare parts, even if they're defective units (which usually makes them cheaper yet!). Many small UHF and microwave components such as tuning and chip capacitors — not to mention several very low noise GaAsFETs and bipolar transistors — are easily removed!

microwave techniques

On the microwave bands (typically 1296 MHz and above), different matching techniques such as the NRAO lossless feedback circuit are often used.[1] The NRAO/W6PO type preamplifier that uses this technique is popular on 1296 MHz.[7] On the higher microwave bands, dielectric, stub, screw, and empirical matching tuners are often used as described in reference 4. Commercial suppliers often use ferrite isolators or hybrid couplers to improve bandwidth and impedance matching.

This month's column mainly referred to VHF and lower UHF operation because this is where most of the activity is. Upper UHF or microwave techniques, a completely separate subject, will be discussed in a future column.

monolithic GaAsFET amplifiers

So far I've mainly addressed homebrew preamplifiers. As I said before, technology moves fast, so it shouldn't be surprising to see that we now have commercial GaAsFET MMICs (Microwave Monolithic Integrated Circuits).[12] Some are simply broadband, moderate-gain (6 to 10 dB) types such as the Microwave Semiconductor Corporation (MSC) CGY-40 and the Nippon Electric Company (NEC) NEPA 1001.[12]

MSC, NEC, Harris Corporation, Pacific Monolithics, and others now supply a broad range of MMIC amplifiers with moderate to high gain as well as entire subsystems through 10 GHz all using GaAsFET technology. These units, typically with 3- to 5-dB noise figures, are usable as medium-performance preamplifiers, but more practically, as second-stage amplifiers. In addition, performance improvements are constantly occurring.

There are a few precautions to observe when using GaAsFET MMICs. Many of these amplifiers require multiple power supplies. Prices are still high, but will drop.

Last month I mentioned the phenomenon of 1/f or low-frequency noise. For illustration, note that the specified noise figure of the Minicircuits Labs model ZHL 1042J broadband GaAsFET amplifier is only 4.5 dB above 100 MHz, but increases to 18 dB at 10 MHz!

tuning and testing

If you can't tune or test a low-noise preamplifier properly, it won't achieve the low noise and moderate gain values that we've discussed so far. However, as I stated previously in both this column and in reference 2, a GaAsFET preamplifier can easily be tuned in line for maximum gain with

only a small degradation in noise figure.

A weak signal source can be used for tuning by having a local Amateur radiate a small amount of rf on your favorite frequency. In this case, the preamplifier should be tuned for best signal + noise ratio (SNR), not gain. This can be tricky at best. EMEers often tune their preamplifiers for maximum sun noise referenced to a quiet sky.[13]

Reference 2 also discussed the "reverse isolation" test, which greatly simplifies the testing of the preamplifier stability margin. For system stability, it's important that the reverse gain (really a loss) be at least 6 to 10 dB greater than the forward gain of a preamplifier. For instance, a GaAsFET preamplifier with a gain of 20 dB should have a loss of at least 26 dB when reversed from end to end. If not, it may not be stable when used in a system that isn't 50 ohms from dc to daylight!

If you're lucky enough to own or borrow the use of a noise figure generator, preamplifier tuneup is considerably simplified. If not, attend one of the many VHF conferences often referred to under "Important VHF/UHF Events" at the end of each month's "VHF/UHF World." These conferences often have the latest in noise figure gear available, which you can use to optimize your preamplifier noise figure and measure your performance against that of your peers.

A few precautions about noise figure generators are in order. For best noise figure accuracy, the so-called "excess noise ratio" of the noise source should be only a few dB greater than the noise figure of the device under test. Furthermore, the VSWR of the noise source must be very low both in the "on" and "off" states.

Low VSWR can be assured only with a highly padded down noise source or one followed by a ferrite isolator; both, however, are sources of inaccuracy. Most of the older noise generators have 15 to 16 dB excess noise. A 10-dB attenuator pad can be added in series with the output, but this will affect absolute accuracy of the results. To solve this problem, Hewlett-Packard has recently introduced the model 346A noise source for use on its popular model 8970 noise figure generator. The 346A noise source has about a 5.2-dB excess noise ratio (versus 15 to 16 dB on the older model 346B) and is highly recommended for optimization of very low noise figure preamplifiers, especially those with GaAsFETs.

Finally, if you really want to "zero in" on the lowest possible noise figure, you must not only tune for optimum noise match, but also optimize the dc operating parameters of the preamplifier. This is most easily accomplished by placing a pot either in series with or as a direct replacement of the source resistor and the resistor in series with the drain (see **fig. 2**).

To prevent excess current, it's advisable to place a small resistor (perhaps 10 to 50 ohms) in series with these pots. This will provide full adjustment capability. With all these "handles" on the preamplifier, you'll have to act like an octopus to tune everything!

special techniques

As mentioned in last month's column, many techniques are available that will allow you to achieve a low noise figure. The most obvious is to use components with the highest unloaded *Q*. Then select a solid-state device with the lowest possible noise figure. This will probably be a GaAsFET below 4 GHz and a HEMT above that frequency. If you can afford a cryogenic cooler, or find one at a surplus sale, they're highly recommended. Don't forget that the optimization of noise figure, as discussed above, is very important.

It should also be obvious from what we've discussed that the temperature of the preamplifier is very important. Therefore, if your preamplifier is mast- or antenna-mounted, it should be shielded from heat or radiation from the sun. The latter is particularly important for EME operation, which often takes place during the day, when the preamplifier is exposed to sunlight.

predictions for the future

Low-noise HEMTs will eventually trickle down to Amateurs, as will even lower-noise GaAsFETs. Who knows? Maybe even lower noise-figure devices will be discovered that can surpass present HEMT performance. There are certainly customers waiting in the wings for any improvements, however small, and we all know that improvements are market driven.

One of the brightest and perhaps most rapidly accelerating technologies is the field of ceramic superconductivity. Every month an improved ceramic material seems to be discovered that can operate at an even higher temperature and still achieve zero resistivity. As I write this, the latest reported superconductivity has taken place at just below room temperatures; if this technology can be applied to semiconductors, noise figures may yet go to 0.0 dB at room temperature!

Although it doesn't affect receiver technology, semiconductor manufacturers have made great strides in the production of *power* GaAsFETs. Some presently available devices will deliver 4 to 7 watts of linear output power up through 10 GHz with gains of 7 to 10 dB. Even higher power devices are being developed.

What this means is that we can now achieve moderate amounts of linear power well into the microwave frequencies (bands) with simple-to-use devices requiring only one or two low-voltage power supplies. There's no longer any excuse for not using antenna-mounted power amplifiers, thus removing one of the last components of loss in the microwave system.

summary

The SOA is rapidly changing. Noise figures are rapidly approaching the ultimate of 0.0 dB. Homebrew GaAsFET preamplifiers are now being used by Amateurs up through 3 cm (10.5 GHz) and perhaps higher. Some of the circuit and construction techniques were described in this and last month's columns.

Commercial Amateur suppliers are now providing SOA GaAsFET preamplifiers up through 10.356 GHz. With the arrival of power GaAsFETs and the use of antenna-mounted receivers and power amplifiers, we'll soon have to rethink our antenna designs and methods to aim our antennas accurately!

new records

In last month's column, I reported that the North American 3-cm (10 GHz) DX record had just been broken. Since then, I've been able to confirm that a two-way QSO took place on July 19, 1987 between Glen Elmore, N6GN/6, in Ball Rock, California (CM89PX) and Bob Dildine, W6SFH/6, in Mt. Frazier, California (DM05MS). They used narrow-band CW on 10.368 GHz for a record-setting DX of 413.8 miles (665.7 km). Both stations were running 200 to 300 milliwatts to 4-foot dishes, with 4.0-dB receiver noise figures. This was a joint effort with four other stations located throughout California. Congratulations to Glen and Bob on their new record!

Next I want to apologize to Jim Crow, WA5ICW, for listing his call sign incorrectly in the last publication of the North American 5760-MHz DX records.[14]

Last but surely not least, the North American 6-cm DX record has recently been extended. On July 4, 1987 Tony Bickel, K5PJR, in Grove, Oklahoma (EM26OP) and Larry Nichols, W5UGO/0, in Campbell, Nebraska (EN00PH) had a two-way CW QSO on 5760 MHz over a distance of 322.2 miles (534.6 km). Both stations were running 5 watts to 4-foot dishes with 2- to 4-dB noise figure receivers. Congratulations to Tony and Larry.

silent key

It is with great sorrow that I report that Willis (Bill) Conkel, W6DNG, an EME pioneer, passed away on July 13, 1987. Bill was on one end of the first two-way, 2-meter EME QSO. He had developed many novel weak signal techniques and built over 30 different antenna systems before he accomplished this feat. In a letter I just

✓ 274

received from OH1NL, the other half of his history-making contact, Lennart told me how they had run 74 EME schedules before their first successful QSO. That's persistence!

Bill had since moved from Long Beach to Lindsay, California. Ironically, he was building up a new 2-meter EME station at the time of his death. I'll never forget our meetings together. We've lost a great experimenter and friend. *SK.*

important VHF/UHF events:

December 13	*Predicted peak of the Geminids meteor shower at 1900 UTC*
December 20	*New moon*
December 21	*± 1 month, winter peak of sporadic E propagation*
December 22	*Predicted peak of the Ursids meteor shower at 2200 UTC*
December 22	*EME perigee*
January 4	*Predicted peak of the Quadrantids meteor shower at 0030 UTC*
January 19	*New moon*
January 19	*EME perigee*
January 23-25	*ARRL January VHF Sweepstakes Contest*

references

1. Joe Reisert, W1JR, "VHF/UHF World: Low-noise Receiver Update — Part 1," *ham radio*, November 1987.
2. Joe Reisert, W1JR, "VHF/UHF World: Low noise GaAsFET Technology," *ham radio*, December 1984.
3. Joe Reisert, W1JR, "VHF/UHF World: 33 cm — An Update," *ham radio*, April 1987.
4. Joe Reisert, W1JR, "VHF/UHF World: Impedance Matching Techniques," *ham radio*, October 1987.
5. Bob Sutherland, W6PO, "Some GaAsFET Preamplifiers," EIMAC Amateur Service Note AS 49-31.
6. Joseph H. Reisert, Jr., W1JAA, "Ultra Low-noise UHF Preamplifier," *ham radio*, March 1975.
7. Bob Sutherland, W6PO, "GaAsFET Preamps for 902 MHz and 1296 MHz," EIMAC Amateur Service Note 49-36.
8. Joe Reisert, W1JR, "Requirements and Recommendations for 70 cm EME," *ham radio*, June 1982.
9. Joe Reisert, W1JR, "VHF/UHF World: Protecting Equipment," *ham radio*, June 1985.
10. "TR Time Delay Generator," 1987 ARRL *Handbook*, Chapter 31.
11. Bob Atkins, KA1GT, "Using a TVRO LNA at 3456 MHz," *QST*, August 1987.
12. Joe Reisert, W1JR, "VHF/UHF World: Broadband Amplifier in Receiver Design," *ham radio*, November 1986.
13. Joe Reisert, W1JR, "VHF/UHF World: Minimum Requirements for 2-meter EME," *ham radio*, August 1987.
14. Joe Reisert, W1JR, "VHF/UHF World: Operating a VHF/UHF Microwave Station," *ham radio*, July 1987.

ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

The magazine was over 50 years old, but the photograph was quite clear. The young man was standing at a desk or drafting board, his head bowed in concentration. Several graphs and a slide rule were visible on the table. He was writing something on a piece of paper, oblivious to the photographer whose picture forever froze in time a glimpse of the young radio engineer at work (see **fig. 1**). Could he possibly have realized that in due course he would found a communications manufacturing empire?

Arthur A. Collins, 9CXX, had embarked upon a risky business — making money manufacturing Amateur Radio equipment. Starting a new company in the depths of the depression was uncertain enough. He was unknown to Amateurs at large, and the market he viewed was very small — fewer than 15,000 hams. And most of them had little money to spend on ham gear! Still, 9CXX's reputation was good — good enough to spur an order for four 1.5-kilowatt, a-m/CW transmitters to be delivered to Admiral Byrd for his forthcoming Antarctic expedition.

Why had the Admiral bought the transmitters from a relatively unknown source? One reason was that 9CXX had handled messages from Byrd at the North Pole when other stations couldn't make the contact. 9CXX had scheduled KEGK, the *S.S. Chantier*, at Spitzbergen on 37.5 meters and had also worked KNN, the *Josephine Ford*, Byrd's Fokker airplane as it flew towards the pole. The Admiral knew a capable fellow when he met one, and the upshot was that Art Collins built the greater share of the transmitting gear for Byrd's trip to the South Pole.

design problems

When 9CXX started designing transmitters for sale to hams, his experience in building his own station was invaluable. He knew how unreliable ham transmitters were! It was an ongoing battle, he knew, to keep a 20-meter phone transmitter on the air — even a small one. And Byrd wanted kilowatt capability all the way up to 16 meters!

In 1933 there were only a few 20-meter phone operators in the world. Other Amateurs looked upon these supermen with awe. Building a low-power 20-meter phone was an exercise in frustration. Tubes ran red in the breadboard rigs. RF skipped merrily through rf chokes and ran down power and microphone cables. The audio system squealed with feedback, meters banged against the pin, and very little rf ever reached the antenna. And the idea of building a kilowatt 20-meter phone transmitter? Out of the question! One or two hams knew — or thought they knew — how to do it, but they kept their plans a secret, or so it seemed.

Art Collins, however, had the concept of systems engineering in his mind decades before the term became popular. Years later, he told me that

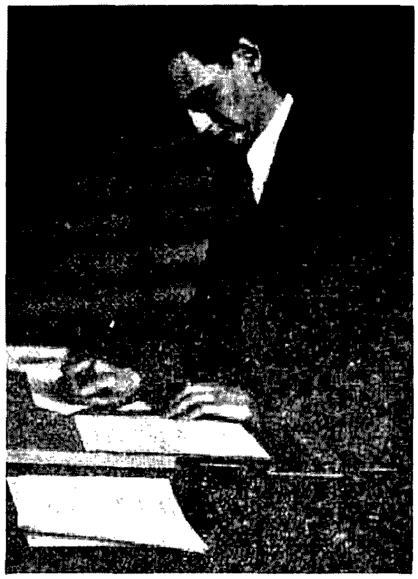


fig. 1. The young Art Collins, 9CXX and W0CXX, at his drafting table, working on transmitter designs for his new company. (Reproduced from *Radio* Magazine, August 1933).

he had broken the difficult design problem down into four areas: how to keep rf where it belonged in the transmitter; how to provide sufficient drive for proper phone operation; how to couple the energy to the antenna; and finally, how to package the whole transmitter so that it could be shipped in working condition to the buyer.

All of these concepts had been discussed in greater or lesser degree in *The Proceedings of the I.R.E.*, but no one had put the ideas together to construct a practical, inexpensive short-wave transmitter that would work on

a large number of frequencies under difficult operating conditions.

Months before the Byrd contract arrived, a small ad appeared in the January 1932 issue of *QST*, announcing "crystal transmitters" of radically new design and capable of high output on 20 meters (**fig. 2**). The transmitters were supplied in kit form, with prices starting at $37.25. The advertiser was Arthur A. Collins Radio Laboratories in Cedar Rapids, Iowa.

The next ad (in the March 1932 edition of *QST*) dropped the kit idea (**fig. 3**). The lowest priced transmitter (presumably not a kit) was now only $33.95 and the company name had been changed to Collins Radio Transmitters. A complete line of power supplies, modulators, and "input equipment" was also listed.

The ad in the May 1932 issue of *QST* suggested that the little company was now a successful business. Shown in the ad was a photo of a 150-watt, 20-meter phone transmitter, resplendent with seven meters and mounted neatly in a steel rack (**fig. 4**). The price? A mere $285.70. (At the time, I mailed a penny postcard to Collins Radio Transmitters asking for full information. Alas, the $33.95 transmitter

fig. 2. Collins kits? Yes, the first ad Art Collins ran in *QST* advertised transmitter kits. He soon saw the folly of this arrangement and thereafter sold only finished products!

fig. 3. Collins was now in the transmitter business. Note that he was also selling auxiliary components. The company had clearly outgrown the "laboratory" concept featured in the first advertisement.

fig. 4. The 150-watt rack-mounted phone transmitter. Quality was so good that the little transmitter was bought by several South American broadcast stations. The sky-high price of $287.50 prevented many Amateurs from buying.

was now $73.60. Regretfully, I concluded I could never afford a Collins transmitter.)

Finally, in early 1933 the Collins company announced the 30W transmitter (**fig. 5**). This was a neat, two-deck job, with four meters (meters were very important in those days). The price was $125.00 Almost as an afterthought, a companion modulator that would "make a phone that really does things" was offered as well.

Interest in the 30W prompted Collins to make a complete, compact phone transmitter — the 32B. The price was held at $125.00.

By mid-1933 the country was starting to come out of the depression. Business was picking up, unemployment had dropped a bit, and people seemed to have a little money to spend. Enough Amateurs bought the Collins 32B transmitter — and liked it — to make Collins a "big name" in the communication industry (**fig. 6**).

To hedge his bet, Collins also brought out a simple CW version of the transmitter, but sales were poor in comparison with sales of the phone version.

fig. 5. The 30-watt CW transmitter was a success among well-to-do Amateurs. By redesigning the circuit, Collins produced the famous model 32A and 32B transmitters. Selling at the same price as the obsolete 30W, the 32B was an instant hit among DX phone operators.

rapid expansion

By autumn of 1933 the Collins Radio Company was in full swing. A full-page ad in the November *QST* revealed an impressive line of transmitting components — transformers built to Collins specs by the Chicago Transformer Company. And in early 1933, the company announced the 150B phone

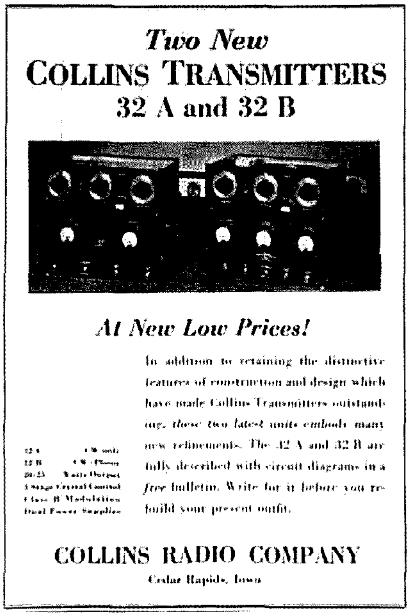


fig. 6. The Collins 32B was the first low-power "all-band" Amateur phone transmitter that worked. Mine is *still* working — on 160 meters.

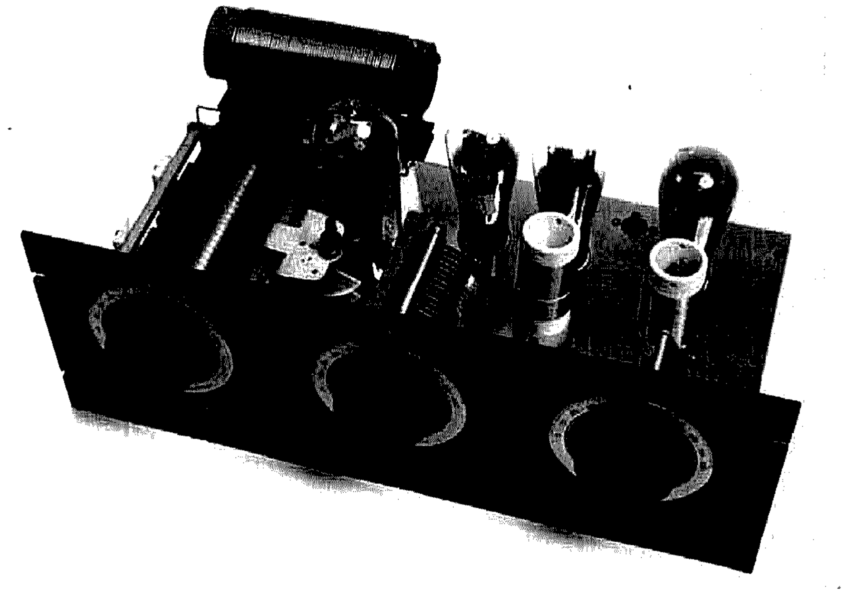


Fig. 7. The popular 150B-series transmitters used a state-of-the-art rf deck that was included in higher power units as well (up to the kilowatt level). The three-stage circuit, built on an aluminum chassis and panel, utilized three plug-in coils to provide operation between 1700 kilocycles and 15 megacycles. Power output was at least 100 watts at any frequency in that range.

transmitter, a 150-watt job that worked on all frequencies up to 14.5 megacycles (MHz). At last a workable 20-meter phone transmitter of moderate power had arrived! It sold for about $350. Best of all, low-power shortwave *broadcast stations were buying* the transmitters in increasing numbers!

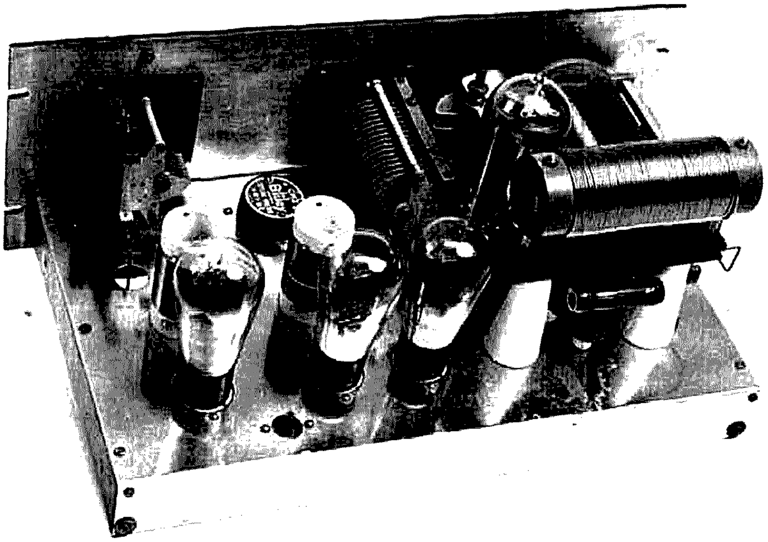


fig. 8. Rear view of the 150B deck. Tuning capacitors were above ground and mounted on insulating plates. Note the wirewound resistor across the power amplifier plate choke. This prevented a parasitic oscillation when the transmitter was operated at the lower frequencies. The buffer neutralization capacitor is mounted below deck, with shaft coming up through the deck. A single 203A "50-watt" triode tube was used in the amplifier stage.

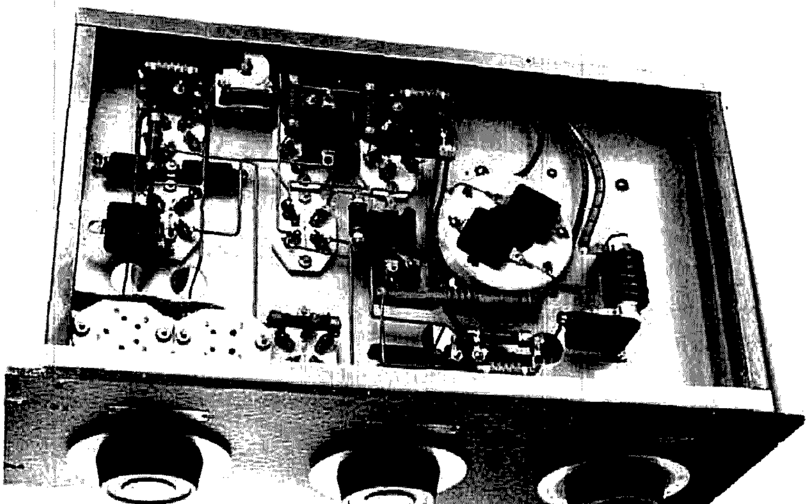


fig. 9. Underview of 150B chassis shows Art Collins's mastery of rf circuitry. Note the small parasitic chokes in the buffer stage circuit and the large parasitic choke mounted parallel to the front panel, near the 50-watt socket. Ample bypassing and use of rf chokes kept the radio energy where it belonged. All connections to the unit were brought out through the two ceramic sockets mounted under the chassis in one corner. All wiring was laced, and rf leads were angled in the approved fashion of the time. All bypass capacitors were encased mica units. (150B chassis from the W6SAI collection.)

the Collins rf deck

The secret of success was Art Collins's knowledge of rf circuitry, as revealed in the 150B. The circuit was quite conventional, and most Amateurs of that period could draw it out on paper from memory. But Art knew the tricks necessary to translate the circuit diagram into a working transmitter (see **figs 7, 8,** and **9**).

The basic transmitter was first sold in early 1933, and with a few circuit and cosmetic changes, it remained in production until late 1935, when newer tubes rendered the design obsolete. At the same time, band switching eliminated the old-fashioned plug-in coils.

The circuit consisted of a 47-pentode tube as a crystal oscillator, two 46 high-μ tubes connected in parallel as a doubler stage, or neutralized amplifier, and a single 203A, 50-watt triode power amplifier. A link coil was used to couple the amplifier to an external antenna tuner.

A circuit similar to this had appeared in the ARRL's *Handbook* for years. But that transmitter was a breadboard affair, and Collins built his on an aluminum chassis to provide better ground return and improved circuit isolation. Interconnecting harnesses ran between the transmitter decks and important power leads were well bypassed to keep the rf where it belonged.

Most important, Art Collins knew about and understood parasitic circuits. Mysterious tube heating, unreliable tuning, and loss of output power — a mystery to most Amateurs and even many manufacturers — were conquered in the 150B rf deck. Mass production of shortwave transmitters heretofore had been costly and frustrating because each transmitter had to be debugged to get it on the air, and each debugging operation seemed different from the previous one!

Not so with the Collins gear. An example of an early parasitic suppression

scheme is seen in the underchassis view of the rf deck. Today, the presence of a noninductive resistor and choke coil is commonplace in large, tube-type linear amplifiers. But that was a new and novel idea in the 1930s.

The reproducibility and docile tuning of the transmitter were so good that Collins advertised that the transmitter was factory neutralized, and the user wouldn't have to worry about that complicated adjustment! This was a refreshing change for Amateurs and professionals who had spent hours vainly trying to tame a wild and unpredictable amplifier!

Art Collins, now W9CXX, had achieved what others had tried but failed to do. He marketed a shortwave transmitter that could be tuned up by the book — and would work! The price was right. As international shortwave broadcasting became popular, more and more Collins ham transmitters were put to this use. Collins started making commercial versions of the ham transmitters, complete with speech consoles and studio equipment. (In 1934 I visited YV3BC in Caracas, Venezuela, and saw three Collins 150-watt phone transmitters adapted for shortwave broadcast service.)

The big transmitters designed for the Byrd expedition were quickly adapted for broadcast and Amateur use (**fig. 10**). The company expanded into the broadcast field and, by World War II, was a fixture in the communications world as a reliable manufacturer of communications equipment of all kinds.

From 1932 to 1942, radio was dominated by this small, upstart company that grew from a one-man shop into a giant in communications (**fig. 11**). World War II brought tremendous expansion to Collins Radio, but I'll leave it to someone else to tell the story of the company from 1942 on.

These stories of "the good old days" were gleaned from Art himself during our occasional meetings over the years. He had many more, but now they'll not be told. Art was a grand person, a good friend of the Radio Amateur, and a technical wizard. Those of us who knew him miss him very much.

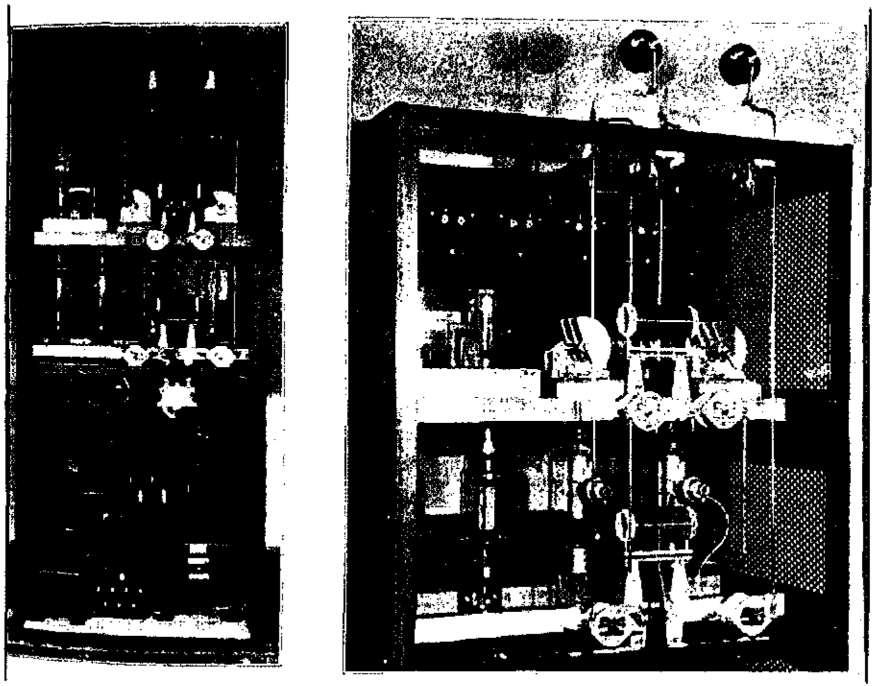


fig. 10. The famous 20B transmitter used by Admiral Byrd at the South Pole. A variation, Model 20C, was sold to Amateurs who could afford the $2700 price tag! The transmitter weighed well over 1000 pounds. W9BHT, XE1G, and W2BSD owned the first three production models.

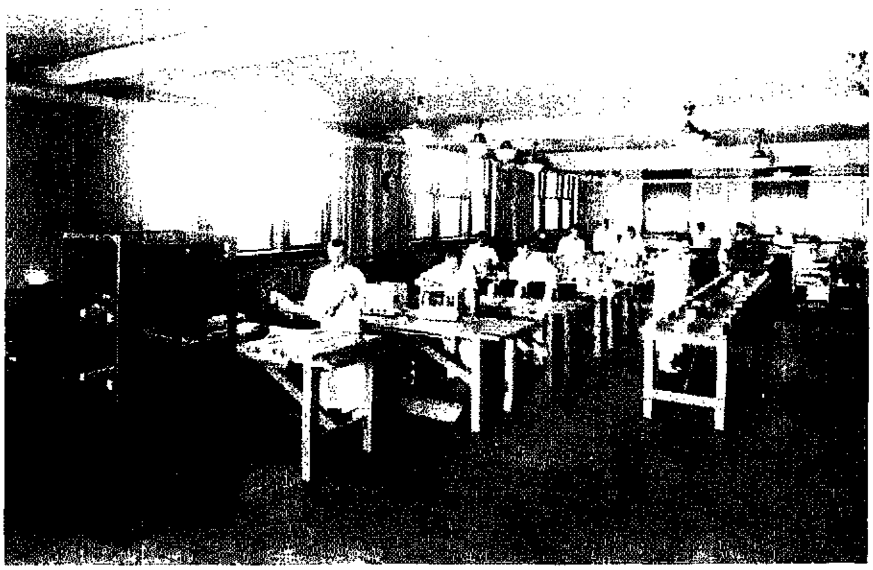
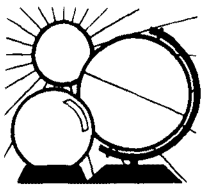


fig. 11. With the 20B transmitter, the Collins Radio Company hit the jackpot. Many of these fine kilowatt phone transmitters were ordered by shortwave broadcasters. Shown in this rare photo is the early Collins production line assembling 20B transmitters. Thirteen workers are visible in this picture; even in the depths of the Great Depression, the company was a success!

Art Collins, W9CXX, died on February 25, 1987.

ham radio



DX FORECASTER

Garth Stonehocker, KØRYW

DXing via the winter anomaly

The increased signal absorption anomaly that results in five- to six-day periods of 20 to 40 dB weaker signals through the mid-to-high latitude propagation paths in winter has been the subject of previous columns.[1,2]

These paths provide our main communication links to European, Asian, and Japanese Amateurs. As discussed in the previous columns, there are exceptions to this anomalous propagation rule; these show up as areas of lower absorption and consequently higher signal strengths. These "windows" can sometimes produce signal levels that *exceed* those received during the normal (optimum) winter low absorption periods. So to emphasize the positive aspects of wintertime DXing, let me summarize the DXing possibilities inherent in taking advantage of this phenomenon.

Table 1 shows the forecasting sequence of events that precede the good signals, and also when they're likely to be best. Anytime during the months from November through February — and possibly into March — look for the progression indicated in **table 1**.

The absorption spreads as it rotates to the west, decreasing in latitude at the same time as shown in **fig. 1** below. The rotation amounts to 30 degrees (two time zones) per day and decreases in latitude from 65 to 30 degrees in the five days of rotation.

To take advantage of the decreased absorption that provides strong DX signals on east, west, and transpolar paths, one has to access WWV or the bulletin board to keep track of the daily geomagnetic A value during this winter season (mainly January). Continue keeping track after each A value of 15 or higher until a STRATWARM is given; after that, consult your map or globe to follow the 90-degree position between the location given for the STRATWARM and its 180-degree companion. Coordinate your beam bearings and the DX path control points (1200 miles from the QTHs "on" the great circle) with the areas of lower absorption on both or on at least one end. If the area isn't right for your DX on that particular day, you can forecast — at 30 degrees of longitude and lower latitude per day — when you can expect good results during the five to six days to come.

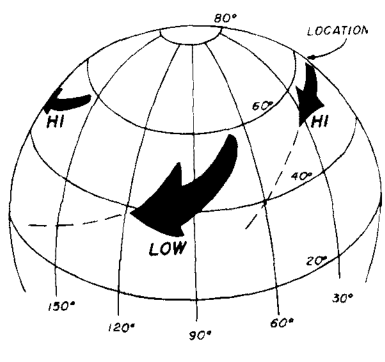


fig. 1. Region of higher absorption moves west and south on a daily basis.

Table 1. Sequence of events preceding best signals.

Day	Condition	Result
0-3	Geomagnetic disturbance, A > 15	(Trigger) Auroral Zone weak signal
3-5	Warm region builds	"STRATWARM EXISTS" (location) on WWV
5-10	Absorption rotates, spreads down	Best signals 90 degrees from location

last-minute-forecast

The higher frequency bands, 10 to 30 meters, are expected to be best the first and last weeks of the month, as well as during half of the preceding and following weeks. Look for good extra-long-skip transequatorial openings to the south during the second week, especially if some days of mild geomagnetic disturbance occur because of the decreasing (relaxing solar pressure) solar flux. The third week of the month — plus a few days on both ends — is expected to be best for daytime short-skip and nighttime DX on the lower bands. Expect other geomagnetic-ionospheric disturbances around the 16th.

The Geminids meteor shower, which will peak on December 13 through 14, will provide the richest and most reliable display of the year, with rates of 60 to 70 per hour. Because optical observations may be difficult or impossible during periods of poor weather in December, actual numbers must be determined by radio reception. A smaller version of the shower will be noted on December 22. The full moon will occur on the 5th, and lunar perigee will occur on the 22nd. Winter solstice occurs on December 22nd at 0946 UT.

band-by-band summary

Ten, twelve, fifteen, and twenty meters provide many openings during the daytime. As you go up in frequency (i.e., into the higher bands) the openings will be shorter, centered around noon, and mainly toward southerly directions. Fifteen meters is only a transition band between 12 and 20. Twenty meters, *the mainstay daytime* band for northerly directions will be useful towards the south in the evenings. Transequatorial openings might occur in evening hours to locations up to 2000 miles away if antenna radiation angles are down to 10 degrees.

Thirty, forty, eighty, and one-sixty meters are all good for nighttime DX.

(continued on page 94)

DECEMBER

WESTERN USA

GMT	PST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	4:00	40	40	20	15	15*	12	12	20
0100	5:00	30	40	20	20	15*	12	12	20
0200	6:00	30	40	20	20	15	15	15	20
0300	7:00	40	40	30	20	20	20	15	30
0400	8:00	40	40	30	20	20	20	20	30
0500	9:00	40	40	30	30	20	20	20	40
0600	10:00	40	40	30	30	20	20	20	40
0700	11:00	40	40	30	30	20	30	30	40
0800	12:00	40	40	30	30	30	30	30	40
0900	1:00	40	40	30	30	30	30	30	40
1000	2:00	40	40	30	30	30	30	30	40
1100	3:00	40	40	30	30	30	30	30	40
1200	4:00	40	40	30	30	40	30	30	40
1300	5:00	40	40	20	15	30	30	30	40
1400	6:00	40	30	15	15	30	30	30	40
1500	7:00	40	20	15	15	20	20	20	40
1600	8:00	40	20	12	12	20	20	20	40
1700	9:00	40	30	12	12	15	20	30	40
1800	10:00	40	30	12	12	15	15	20	40
1900	11:00	40	40	12	10	15	15	20	40
2000	12:00	40	40	12	10	15	15	20	30
2100	1:00	40	40	15	10	15	12	15	20
2200	2:00	40	40	15	12	15	12	15	20
2300	3:00	40	40	20	12	15	12*	15	20

MID USA

GMT	MST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)	CST
0000	5:00	40	40	20	20	15*	12	12	40	6:00
0100	6:00	40	40	20	20	20	15	15	40	7:00
0200	7:00	30	40	30	20	20	20	15	40	8:00
0300	8:00	40	40	30	20	20	20	20	40	9:00
0400	9:00	40	40	30	30	20	20	20	40	10:00
0500	10:00	40	40	30	30	20	30	20	40	11:00
0600	11:00	40	40	30	30	30	30	30	40	12:00
0700	12:00	40	40	30	30	30	30	30	40	1:00
0800	1:00	40	40	30	30	30	30	30	40	2:00
0900	2:00	40	40	30	30	30	30	30	40	3:00
1000	3:00	40	40	30	30	30	30	30	40	4:00
1100	4:00	40	30	15	20	30	30	30	40	5:00
1200	5:00	40	30	15	15	30	30	30	40	6:00
1300	6:00	40	20	12	15	30	30	20	40	7:00
1400	7:00	30	20	12	15	20	20	20	40	8:00
1500	8:00	40	20	12	12	20	20	30	40	9:00
1600	9:00	40	30	10	12	20	20	20	40	10:00
1700	10:00	40	30	12	12	15	20	20	40	11:00
1800	11:00	40	40	12	10	15	15	30	40	12:00
1900	12:00	40	40	15	10	15	15	20	40	1:00
2000	1:00	40	40	15	12	15	15	20	40	2:00
2100	2:00	40	40	12	12	15	12	15	20	3:00
2200	3:00	40	40	12	12	15	12	15	30	4:00
2300	4:00	40	40	20	15	15*	12	15	30	5:00

EASTERN USA

GMT	EST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	7:00	40	40	20	20	20	15	20	40
0100	8:00	40	40	30	20	20	20	20	40
0200	9:00	40	40	30	20	20	20	20	40
0300	10:00	40	40	30	20	20	20	20	40
0400	11:00	40	40	30	20	20	30	30	40
0500	12:00	40	40	30	30	30	30	30	40
0600	1:00	40	40	30	30	30	30	30	40
0700	2:00	40	40	30	30	30	30	30	40
0800	3:00	40	40	30	30	30	30	30	40
0900	4:00	40	40	30	30	30	30	30	40
1000	5:00	40	30	15	30	30	30	30	40
1100	6:00	40	30	15	20	30	30	30	40
1200	7:00	30	20	12	15	30	30	30	40
1300	8:00	40	20	12	15	20	20	20	40
1400	9:00	40	20	12	15	20	20	20	40
1500	10:00	40	20	10	12	15	20	20	40
1600	11:00	40	20	10	12	15	20	20	40
1700	12:00	40	20	12	12	15	20	30*	40
1800	1:00	40	30	12	10	15	15	20	40
1900	2:00	40	30	12	10	15	15	20	40
2000	3:00	40	40	15	12	15	15	15	40
2100	4:00	40	40	15	12	15*	12	15	40
2200	5:00	40	40	20	12	15*	12	15*	20
2300	6:00	40	40	20	20	15	12	15	30

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

Thirty and 40 meters are the night frequencies for the east, west, and northerly directions, and for distances of 1600 miles if increased solar activity has occurred. With little solar activity, the MUF will approach 80 meters and signals will usually be stronger there. These bands should generally be quiet and stable, since thunderstorm activity is not pronounced and December is a geomagnetically tranquil month.

ham radio

product

REVIEWS

pc-pakratt terminal program for the PK-232

One of the biggest problems many Hams encounter in getting on packet radio is making their home computers "talk" to their TNCs. Despite the claims of software houses ("easy to use," "sets up in minutes!") — don't believe it. Unless you're a computer whiz, it doesn't happen that way . . . or at least it *didn't* happen that way until AEA released its new MS-DOS Packet terminal program for the PK-232. Designed for those of us without EE degrees, PC-PAKRATT allows use of the PK-232 with a minimum of hassle and problems.

PC-PAKRATT will run on all IBM PC-XT or AT machines and most compatibles. You need to be running DOS 2.0 or a later version, have at least 320K internal memory, have a RS-232 serial port, and two 360K floppy drives. If you're using a compatible and it will run one of the flight simulation games, chances are PAKRATT will work OK for you.

PC-PAKRATT requires ROM chips dated 1987 or later to work properly; if you have chips dated October 1986 or earlier, contact AEA for upgrade information.

installation

Before you begin, you'll want to make a working copy to protect the original from mistakes or other glitches.

Remove the batteries from the internal battery supply. The PC-PAKRATT program will store your callsign and other important information on the program disk. Connect the TNC to your computer, boot your operating system, install the PC-PAKRATT program, and you're just about ready to go.

The first screen you'll see is *Log On*; with this one, you'll be able to choose the most appealing or easy-to-read colors for the screen and text, select communications port 1 or 2, and set the TNC-to-computer baud rate. Hitting the space bar initiates communications between computers; in about 15 seconds you should see the main screen display. If there's a problem, the screen will give you an error message. A quick look in appendix A of the program manual will identify the error and suggest an appropriate fix.

main screen

Now that the program is up and running and the computers are talking to each other, it's time to learn all the subtle nuances of the program. AEA has tried hard to make the PAKRATT as simple and as easy to use as possible. Commands are straightforward and easy to remember: P = print, R = rename, S = erase, and so on. You can edit and browse using the B command, and you can set up two user-defined files. Of particular interest, AEA has provided a "softkey" or user-designed macro that can be used to save time as you enter repetitive commands. You can store as many as 20 different sequences of up to 256 keystrokes.

mode screens

The packet display is divided into three windows or areas. At the top, the status line lists transmission mode, link status, buffer status, link state, and several other important parameters. The second section, the receive window, displays all the data received by the TNC. The third, the transmit window, the information you're about to transmit.

A number of special keys are provided to help reduce the amount of time needed to make any command changes. F1 brings up the HELP screen; F2 is *AUTO CONNECT*; F3 is *CONNECT*; and F4 DISCONNECT, and so on.

The Morse, Baudot, ASCII, AMTOR, and FAX screens are similar in layout and operation. There are divided screens for both receive and transmit as well as plenty of special keys to enhance and speed operation on each mode. These special keys are designed to simplify operation to the point that it's hard to forget how to use the equipment even after a long layoff. You can also use your computer as a dumb terminal to facilitate PK-232 calibration and SIAM operation.

As if that weren't enough, PC-PAKRATT will also emulate MicroPro's WordStar program as a screen editor program. You can create, modify, or examine most files in the system. You can also look at and make changes to the QSO buffer.

conclusion

All in all, this is a super program. When I first got "digitized," I spent hours setting up my system, then getting the computers to talk to each other. As of now, I've spent three hours trying to get a supposedly easy-to-work dumb terminal to talk to the PK-232; it took about 10 minutes to get PC-PAKRATT to work on my IBM-clone computer.

One distinction needs to be made. PC-PAKRATT doesn't give you hundreds of unique features that aren't found in other communications software packages. PC-PAKRATT does give you, however, everything you need to use the PK-232 to its fullest potential. It also greatly simplifies operation through its carefully structured commands. And, I'm sure that as PAKRATT gets into the hands of more users, it will continue to evolve in ease of operation and overall power.

AEA has just announced the availability of a C-64 program that provides many of the same features as PC-PAKRATT.

You can see PC-PAKRATT in operation at your local AEA dealer or contact the manufacturer (AEA, 2006 196th Street SW, Lynnwood, Washington 98036) for more information.

Circle #301 on Reader Service Card.

— de N1ACH

NEW products

new 10- and 6-meter base station transceiver

The new IC-575A is a 10-meter and 6-meter dual-band base station transceiver. This wide-band, all-mode base receives 26 to 54 MHz continuously and has 99 tunable full function memories, passband tuning, a notch filter, noise blanker, built-in SWR bridge, semi- or full CW break-in and a multi-function meter. The IC-575A also has a velvet-smooth tuning knob and easy-to-read amber LCD readout with variable backlight.

Four scanning systems are available: band, programmable, mode and memory scan with selectable lock-out (scans 99 memories in five seconds).

All subaudible tones are built in, and the actual subaudible frequency is displayed. Standard repeater splits are built in and odd splits are programmable.

For packet enthusiasts, the IC-575A incorporates DDS (Direct Digital Synthesizer).

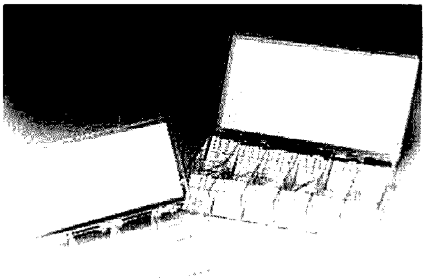
The 10-watt IC-575A is similar in design to ICOM's compact base station line: the IC-735, IC-275A, IC-275H and IC-475A.

Information concerning price and availability can be obtained by contacting ICOM America, Inc., 2380 116 Avenue N.E., P.O. Box C-90029, Bellevue, Washington 98009-9029.

Circle #302 on Reader Service Card

chip resistor and capacitor kits

Communications Specialists, Inc. has introduced a series of chip resistor and capacitor kits. Intended as prototyping kits for engineers, they may also be used as parts kits for repair technicians and experimenters. Kit CR-1 contains 1540 pieces composed of: 10 chip resistors of



every 5 percent value from 10 ohms to 10 megohm (145 values + 0 ohm jumper), plus a bonus of ten additional resistors in the eight values of 0, 10, 100 ohms; 1, 10, and 100 k, as well as 1 and 10 meg. Resistors are 0.10-watt 0805 size to 3.3 megohms, and 0.125-watt 1206 size above 3.3 megohms. Tolerance for all is 5 percent, and each resistor is marked with its three-digit value.

Kit CC-1 contains 365 pieces composed of five chip capacitors of every 10 percent value from 1 pF to 0.33 μF (67 values), plus a bonus of five additional capacitors.

Each kit sells for $49.95; both are available for immediate delivery from stock. For a free brochure describing both kits, or to order, contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665.

Circle #303 on Reader Service Card.

new packet options

A new high-speed pc board packet modem option for the Kantronics All Mode (KAM) and KPC-4, the 2400 Kantronics Modem™, plugs right in to existing KAM or KPC-4 boards to provide optional 2400-bps packet operation, selected by use of the EXTMODEM command. When installed in the KPC-4 (only), use of the **ONE-RADIO** command permits mixed 1200/2400-bps data rates on a single frequency. The new 2400 Modem retails for $69.95.

Kantronics is also offering the Version 2.70 feature enhancement update for existing KAM units and KPC packet units. The Version 2.70 update adds the three KISS commands that make the KAM and KPCs TCP/IP networking compatible. Additionally, the update adds the popular Personal Packet Mailbox feature to each unit, allowing you and others to leave and retrieve messages in your packet or All Mode unit. The update is available for the KAM Packet Communicator, KPC-2, KPC-2400, and KPC-4 units for $15.00, and free to those who purchased lower level units after July 1, 1987 and can show a dated sales receipt.

As of July 31, 1987, Kantronics began providing additional features at no extra charge; all Kantronics KAMs and KPC packet units shipped from the factory included the Personal Packet Mailbox, 32K RAM, and TCP/IP networking compatibility. Current KAM and KPC owners can add the Personal Packet Mailbox and TCP/IP compatibility to their unit for the special price of just $15.00; a 32K RAM expansion chip is available for $15.00.

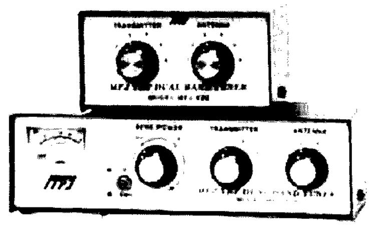
For more information, contact Kantronics, Inc., 1202 East 23 Street, Lawrence, Kansas 66046.

Circle #304 on Reader Service Card.

dual-band VHF antenna tuners

MFJ Enterprises, Inc. has introduced two new dual-band VHF antenna tuners that cover both the 144-MHz and the new Novice 220-MHz bands. Both handle 300 watts PEP, match a wide range of impedances for coax-fed antennas, and are built into rugged all-aluminum cabinets painted eggshell white with a black top.

The MFJ-921 has a built-in SWR/Wattmeter, measures 9 x 2 x 3 inches, and retails for $69.95. The MFJ-920 measures a compact 4-1/2 x 2 x 3 inches and retails for $49.95.



Both come with a one-year unconditional warranty. If either is ordered directly from MFJ Enterprises, Inc., it can be returned within 30 days for a full refund (less shipping and handling) if you're not satisfied.

For additional information, contact MFJ Enterprises, Inc. at P.O. Box 494, Mississippi State, Mississippi 39762.

Circle #305 on Reader Service Card.

tool cases, catalog

Two new tool cases are featured in Jensen's new 160-page, full color catalog. Rotationally molded of high density polyethylene, these Rota-Lux and Rota-Tough cases are available options for Jensen's tool kits, including the top-of-the-line JTK-87 Electronic Service Kit for field service engineers.

Rota-Lux and Rota-Tough cases vary slightly in size and styling. All Rota-Lux cases measure 17-3/4 X 12-3/4; Rota-Tough cases measure

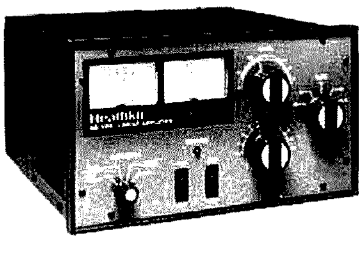
17-3/4 X 14-3/4. Five models, differing in depth from 5 inches to 10 inches, are available.

For information and a copy of Jensen's new catalog of electronics tools and test equipment, contact Jensen Tools, Inc., 7815 South 46th Street, Phoenix, Arizona 85044.

Circle #306 on Reader Service Card.

linear amplifier kit

Heathkit's new SB-1000 linear amplifier provides a full 1000 watts PEP output on SSB or 850 watts output on CW. It provides full HF coverage from 160 to 15 meters, including 80 percent of rated output on the three WARC bands. The SB-1000 Linear Amplifier uses a single 3-500Z tube in a high-efficiency circuit and has a hypersil steel E-I core transformer for high-performance operation. It also features a quiet



computer-style fan, a stiff full-wave power supply with computer-grade capacitors, adjustable ALC, and plate and load controls with smooth vernier tuning.

For more information about the SB-1000 Linear Amplifier and Heath's expanding line of Amateur Radio equipment, contact Heath Company, Dept. 150-955, Benton Harbor, Michigan 49022. (In Canada, contact Heath Company, 1020 Islington Avenue, Dept 3100, Toronto, Ontario, M8Z 5Z3.)

Circle #307 on Reader Service Card.

scanner/computer interface

The Engineering Consulting Model 727S scanner interface for the Yaesu FT-727R and the Commodore 64 computer provides a high quality, feature packed scanner. The entire radio channel memory can be loaded in under 15 seconds at 4800 baud. All parameters are stored and up to ten sets of ten channels can be scanned. Information can be saved to disk, which allows 100 channels per disk. All ten memory groups can be scanned at once or individually. Scan lock-out for individual channels is provided. The scan speed and resume time are adjustable. All transmit and receive frequencies plus offsets and encode/decode sub-tones can be input and load into radio on command. Return data from the FT-727R provides a full-screen digital S-meter which may be used to stop the scan on preset signal strengths from S-1 to S-9. A comment field is provided for each channel entered and is displayed while scanning the channel. All information for each channel programmed (in groups of 10) is simultaneously displayed on the monitor.

Once the channels are entered via the computer keyboard the information in any of the ten frequency groups may be downloaded to the HT for portable use. All 100 channels may be scanned as one group while under computer control. The model 727S is supplied with hardware and software to operate with the Commodore 64/64C/C128/SX64 series of computers. The hardware interface includes the circuit board, components cables, instructions and connectors necessary (in kit form). Assembly time is approximately 10 minutes, and it makes a great club project.

For further information, contact Engineering Consulting, 583 Candlewood Street, Brea, California 92621.

antenna rotor

Encomm's new KR-1000SDX azimuth antenna rotor from Kenpro includes features such as 450-degree rotation for easy, speedy antenna pointing; North, South, East, or West-centered readout capability; variable speed rotation control for fast (less than 43 seconds) 360-degree rotation; and preset direction control with automatic movement control. In addition, it features gentle antenna handling, with preset and soft landing automatic slowdown before stop; its weatherproof outside connector resists corrosion and decay of wiring. There's room inside the control box for an optional computer interface board area. Limit switches at 450 degrees are included.

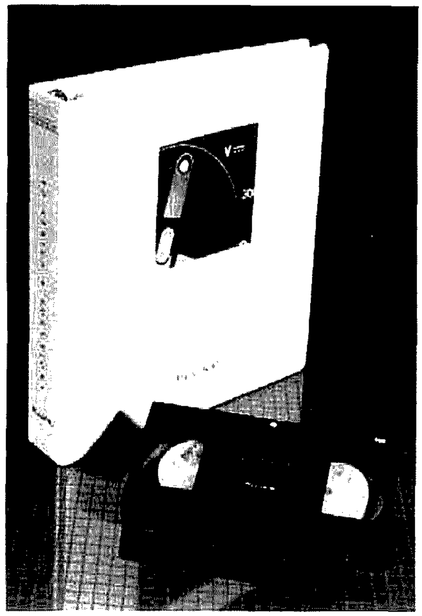
KR1000s (without preset and speed control) are also available. The KR-1000SDX is priced at $489.00; the KR-1000, $399.00. For further information, contact Encomm, Inc., 1506 Capital Avenue, Plano, Texas 75074.

Circle #308 on Reader Service Card.

handheld meter training package

The John Fluke Manufacturing Co., Inc. has announced the availability of a video training package designed to maximize the usefulness and safety of Fluke's 70 Series of handheld digital multimeters.

Titled "70 Series Solutions," the package is intended for industrial or vocational training applications. In addition to a 15-minute video tape, it includes numerous classroom tools such as overhead transparencies, a 100-page instructors guide, and 25 student workbooks.



The training emphasizes "hands-on" exercises, with only a minimal amount of theory presented. Instead, examples of how to make a wide variety of basic measurements accurately and safely are given by demonstration. Many of the unique features of the 70 Series DMMs are also explained.

For details, contact John Fluke Manufacturing Co., Inc., P.O. Box C9090, Everett, Washington 98206.

Circle #309 on Reader Service Card.

Bilal relocates

Bilal Company, manufacturer of Isotron antennas for 160 through 10 meters, has moved from Oklahoma to Colorado. Owner Ralph Bilal reports that the new location is great, and that the company has enjoyed a very busy summer season, despite the move.

The new address is: Bilal Company, 137 Manchester Drive, Florissant, Colorado 80816.

Circle #310 on Reader Service Card.

ham radio cumulative index

1983-1987

ANTENNAS AND TRANSMISSION LINES

general

hf antennas

vhf antennas

matching and tuning

towers and rotators

transmission lines

AUDIO

COMMERCIAL EQUIPMENT

COMPUTER-AIDED DESIGN

CONSTRUCTION TECHNIQUES

DIGITAL TECHNIQUES

FEATURES AND FICTION

FILTERS

FM AND REPEATERS

HAZARDS

INTEGRATED CIRCUITS

KEYING AND CONTROL

MEASUREMENTS AND TEST EQUIPMENT

MICRO-PROCESSORS, COMPUTERS AND CALCULATORS

MISCEL-LANEOUS TECHNICAL

NOVICE READING

OPERATING

OSCILLATORS

PACKET

POWER SUPPLIES

PROPAGATION

RECEIVERS AND CONVERTERS

general

hf

vhf

RTTY

SATELLITES

SEMI-CONDUCTORS

SINGLE SIDEBAND

SOFTWARE

TELEVISION

TRANSMITTERS AND POWER SUPPLIES

general

hf

TROUBLE-SHOOTING

VHF AND UHF

general

antennas

receivers and converters

transmitters

ELMER'S NOTEBOOK

Tom McMullen, W1SL

the 1200-MHz band

This month I'll explore some of the activities and peculiarities of the 1200-MHz (23 cm) band, and give you a tip on how to become a very popular person with your local UHF crowd.

It wasn't too long ago that the 1200-MHz *band* was a *real* challenge for technically sharp Amateurs; getting a few milliwatts of stable power was difficult, and getting several watts required a whole bench full of tubes in cavities, heavy power supplies, blowers to keep it all cool, and enough spare surplus triodes to inflate the price of silver beyond reason. How things have changed!

A sketch of the 23-cm band is shown in **fig. 1**; note that the portion in which Novices can operate covers a large chunk of territory — almost half the band.

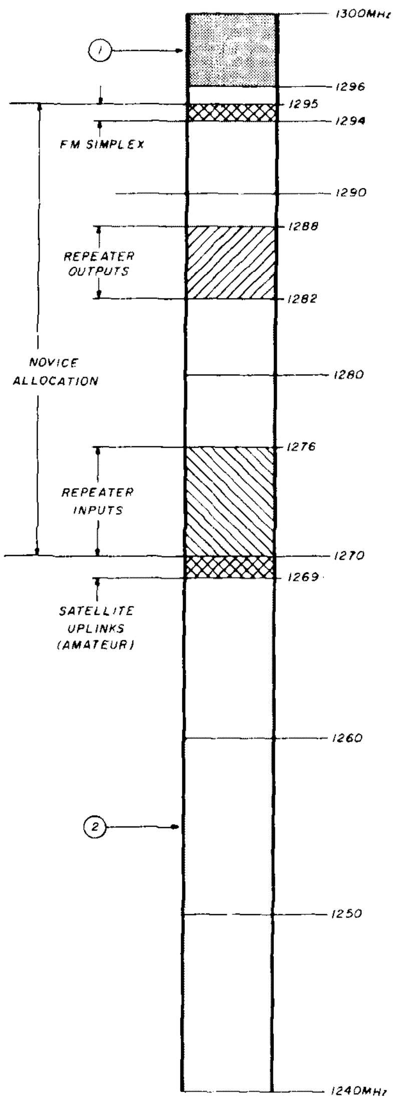


fig. 1. Novice privileges in the 1240- to 1300-MHz band include repeater operation and a large amount of spectrum where other activity can take place.

what's happening?

This is another band in which Novices can use repeaters, and perhaps one of its most promising activities. The power limitation of 5 watts PEP (peak envelope power) shouldn't create hardship at all. Any decent repeater on this band will have a high-gain, non-directional antenna, and it should be able to hear a 5-watt mobile or hand-held unit for several miles. Since a repeater transmitter can operate with many watts of output, the higher power level plus the antenna gain will assure full-quieting signals into any transceiver it can hear.

Repeater channels for fm on the 1200-MHz band are 25 kHz apart, with inputs starting at 1270.05 and continuing through 1276 MHz. Output frequencies are 12 MHz higher, from 1282 through 1288 MHz. There's room for simplex channels between 1294 and 1295 MHz, again with 25-kHz spacing recommended. There's plenty of room between 1276 and 1282, and between 1288 and 1294 for other modes, which I'll discuss later.

Adopted by the ARRL Board of Directors, this band plan has been widely publicized. Local groups may have different ideas, however, so be sure to check what's available before locking into a range of frequencies.

equipment

A look through the advertisements in any Amateur magazine shows that there are several choices for Novices to use on 1200 MHz. One notable fm unit is the IC-12AT hand-held unit from ICOM. It has 1-watt output, and has a sensitivity of 0.32 μV for 12-dB SINAD (and that's pretty good, considering that in the "weak-signal" work of only a dozen years ago, anything that could hear 0.5 μV was considered high techl). One caution, however: current ICOM literature shows the IC-12AT (American version) available with 10, 20, 30, 40, or 50 kHz steps. Their IC-12E (European version) is available with 12.5, 25, 37.5, 50, or 62.5 kHz channel spacing. Be sure the one you get will fit the channel spacing available in your area.

There are a couple of mobile/portable units available: Kenwood's TR-50 (with 1-watt output) and ICOM's IC-120 (also with 1-watt output). Both units can be used mobile, or, given

their relatively low battery-power requirements, portable with a small battery pack.

ICOM also offers a repeater, the IC-RP1210. Novices can't be owners or control operators of repeaters, naturally, but I hope some Elmers or Technicians (who can also be Elmers) will get some ideas. This repeater provides inputs from 1271.02 to 1272.98 MHz, with outputs 20 MHz higher — i.e., 1291.02 to 1292.98 MHz. Output is 10 watts. It will work from either 117V/240V ac, or from 13.8V dc.

Then there's ICOM's IC1271. Again, it has too much power output (10 watts) for the Novice, but it's nice to know about when thinking of upgrading. It's a CW/SSB/fm transceiver, and has all the bells and whistles you'll need for OSCAR, contest, or other weak-signal work. It works from a 13.8-Vdc supply, so it's a good candidate for mobile or home use.

is fm all there is?

There's plenty of other activity going on in this part of the spectrum, and a look at the VHF/UHF/microwave contest scores in *QST* shows quite a few stations adding to their total by using 1296-MHz equipment. This usually comes under the heading of weak-signal work, and there's equipment available for that, too. Note that although equipment shown in most advertisements is listed as 1296-MHz gear, it works at other frequencies too, and usually won't need any adjustment if you put it to work just below 1295. It will require only minor tweaking if you want to use it between 1288 and 1294 MHz.

Weak-signal modes are CW or SSB, and most stations use their existing hf or VHF gear along with converters or transverters (transmitting/receiving converters) for 1200-MHz work. A popular line of such converters and transverters is produced by Microwave Modules. Among the equipment offered is the MMT 1296/144G — a 2-watt output transverter that uses a 144-MHz transceiver as its transmitting and receiving i-f; the NMK 1296/144 receiving converter that uses your 2-meter receiver tuned to the i-f output; and the MMG 1296 MHz receiving preamplifier to provide more gain and low noise ahead of a converter. Microwave Modules also has other units with more power capability for when you upgrade.

Most of the test equipment available in the usual ham workshop will function just as well at 1290 MHz, with the possible exception of a power/SWR meter. Here, the Bird series of wattmeters with plug-in elements offers an accurate means of checking your transmitter power output and antenna SWR.

Frequency counters, too, have arrived in this part of the spectrum: the Optoelectronics model 1300H works up to 1.3 GHz (1300 MHz), and Ramsey offers the CT125 for this band.

antennas

Although commercially-made antennas for this band are available, the selection isn't large. There is evidence of improvement, however. Of course, Kenwood and ICOM provide antennas to work with the equipment they sell, and Larsen has a mobile 1200-MHz antenna available. I've also noticed mobile and base-station/repeater antennas made by NCG Company. Some of the NCG units are dual-band, working at both 446 and 1200 MHz.

For weak-signal work, most people roll their own, and considering that the length of a half-wave element at 1290 MHz is approximately 4-3/8 inches, it isn't hard to put together a beam of respectable gain with a few pieces of aluminum.*

The loop Yagi, which consists of several closed metal hoops mounted on a boom in the same manner that elements are in ordinary Yagi antennas, is a popular item among many enthusiasts. Down East Electronics, Spectrum International, and Mirage/KLM offer loop Yagis.

the television question

Novices are permitted to use all available modes on the 1270-1295 band segment, and that includes television. The obvious precaution, however, is to be sure that television operation doesn't interfere with any repeater operation. A TV signal requires a lot of room — anywhere from 3 to 8 MHz, depending upon the equipment used. There's plenty of space for TV and other modes on the band, but the prudent operator will check to see where others are operating before putting a signal on the air.

The next thought that comes to mind is *How?* I haven't seen any ready-made 1200-MHz television transceivers offered in the Amateur publications. There are, however, 420-MHz television systems and components available. Getting a signal on the air involves applying the video-output signal to an rf amplifier to produce amplitude modulation, then feeding the rf signal through some filters to get rid of one sideband and then to the antenna. Another method is to apply a low-power (i.e., milliwatts) output from a 420-MHz TV generator to a transmitting converter, then mix it with a local oscillator to produce 1200-MHz output. Either way, getting a television station together isn't a terribly difficult procedure, and such a project can easily be explored by the technically adept Novice or Elmer.

safety precautions

One of the reasons for the 5-watt limit for Novices on 1270 to 1295 MHz is the possibility of tissue damage from rf energy at these frequencies. The problem comes about because unlike 28- or 220-MHz energy, for example, 1200-MHz energy is concentrated in a small area. Look at it this way: if you're operating at 28.1 MHz and using a 1/4-wave whip, the output power is distributed along the length of the whip — approximately eight feet. The portion of it that your hand, arm, or head might intercept is small com-

*A note for those who prefer to work with metric figures: the 1240-1300 MHz band is called the 23-cm band, which is one wavelength in space. A half-wave in space is then 11.5 cm, but the diameter of the metal rod used for an antenna element reduces the resonant length. Using the formula L (mm) = 142,250/f(MHz) gives a half-wave element dimension of 110.27 mm, or 11.03 cm, which is a good ball park figure to start with at 1290 MHz.

pared to its total length. At 1200 MHz, however, the antenna length is 4 inches, which means that your hand can intercept most of the energy if you get too close. Even worse, your eye (which is *very* susceptible to rf damage) is of significant size compared with the energy distribution area, and can be severely damaged by exposure. Microwave ovens operate only 1000 MHz higher, at approximately 2300 MHz, and you know what they do to things in their rf fields.

Allowing newcomers to this part of the spectrum to become familiar with operating procedures and technical requirements at a power level low enough to reduce hazards is a very good move on the part of FCC.

A good precaution is to make sure that antennas are high enough so that they don't present any hazard, from either direct contact with their elements or from the concentrated energy (as in front of a high-gain Yagi) they emit.

feed line losses

All transmission lines lose some of the energy they're carrying between the transmitter and the antenna, and the higher the operating frequency, the more they lose. At 1290 MHz, RG-8/U or RG-213/U cable loses 11 dB per 100 feet. That means that if you have 5 watts going into the cable at your transmitter, only 1 watt is reaching the antenna in an average run of 60 feet. Obviously, you should use the shortest feedline you can. Don't scrimp on quality. Foam RG-8/U isn't bad (it loses approximately 6 dB/100 feet) and 1/2-inch hardline is even better at approximately 3.5 dB/100 feet. Buy the best you can get, and use good, clean coaxial connectors. The type-N fitting is best, but where space is a problem, the BNC will serve.

As for using RG-58/U cable (with 22-dB loss per 100 feet), and the so-called UHF (SO-239/PL259) fittings, don't even think about it. These connectors do terrible things to the feedline SWR at 1200 MHz, and most are pretty good attenuators, too.

signal attenuation

Normal atmospheric propagation holds no surprises as far as signal loss is concerned. Buildings will reflect 1200 MHz very well, as will some foliage. By the same token, foliage will absorb the signal, so getting an antenna up in the clear is very important. Mobile flutter (picket-fencing), caused by moving around, will be less noticeable because of the short distance between wavelength peaks and valleys.

One phenomenon that seems to work in a manner opposite from signal attenuation at 1200 MHz is called "ducting." This is caused by layers of air of different densities and moisture content forming channels that reach great distances — sometimes hundreds of miles. These channels seem to behave as waveguides, letting the signal bounce between layers with almost no loss until they pop out at the other end of the pipeline, often with S9+ strengths. Ducting seems to be more prevalent over or near large bodies of water.

Oddly enough, a higher-frequency signal such as 1200 MHz will come through very strong, even though a lower frequency such as 144 MHz won't do well at all. Many UHF enthusiasts have been surprised by scanning a "dead" band, only to have a voice from DX-land come booming out of the speaker.

how to be a hero

Here's a way to become a very popular person. There are several contests a year involving VHF and UHF operation. Stations operating on the higher bands are always in great demand. For example, in the ARRL UHF Contest (usually in August), each contact on 1290 MHz counts as six points, and the total number of grid squares (see below) on each band becomes the multiplier. You can grab one of the portable rigs described earlier, a couple of spare battery packs or whatever, plus 10 or 12 feet of collapsible mast and a small beam antenna. Get to the highest place you can (a hilltop, a tall

building) and have a ball racking up the contacts. Many of the stations will be using a frequency very close to 1296.0 MHz, so you'll have to spread the word that you're only a MHz away at 1295, but once they know you're there, you'll have plenty of calls to answer. This contest includes 220 MHz too, so you could easily become a multi-band contest operator.

Another popular activity on UHF is filling in grid (locator) squares to earn points toward a certificate. A simple portable setup, with a medium-sized Yagi, operating from choice locations in some nearby grids will earn you points with the local VHF/UHF group. Get in on the fun yourself — see page 17 of W1JR's column in the July, 1987, issue of *ham radio* for a copy of the ARRL grid locator map, and start earning your own award. You'll need only 25 grid-square contacts to win your first certificate on 1290 MHz.

ham radio

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (not all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

TEST EQUIPMENT WANTED. Don't wait — we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at Skagitronics Co. (800) 356 TRON

"HAMLOG" COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7 band WAS, DXCC. Full features. Apple $19.95. IBM or CP/M $24.95. KA1AWH, POB 2015, Peabody, MA 01960

RV OPERATORS are invited to check in: Sun 2 PMC, 14.240 ± 5. Tues, Thurs 8 PMC 3.880 ± 5. Good Sam RV Net. Info SASE KJ4RO

FOR SALE: Kenwood TS-940S and TL-922A. Tel. 1 401 789 1817.

2.4 MHz AM Demodulator with 8 bit A-D and buffer. Copy WEFAX from GOES SATELLITES or APT from NOAA POLAR ORBITING SATELLITES. Created for use with Elmer Schwittek's Multifax 2.0 program. Order #206-KIT $49.95 or assembled and tested board Order #206-ASY $69.95. Add $2.50 shipping per order. For info on all our WEFAX products send SASE to: A & A Engineering, 2521 W. LaPalma, Unit K, Anaheim, CA 92801. (714) 952 2114

YAESU FT-727-R COMPUTER INTERFACE. For info write Gerald Fogsett Consulting, 1581 Woodland, Palo Alto, CA 94303.

NJ-NJ-NJ-NJ-NJ-NJ-NJ-NJ A Full Service Ham SWL CB Scanner store in NJ. Discount Grand Opening Prices. Top performing radio systems for every budget. New 10 meter and VHF/UHF rigs. ARRL, Amphenol, Astatic, Astron, Azden, B&W, Bilal Belden 9913, Butternut, Clear Channel, KLM, Larsen, MFJ, Mirage, Mil Spec Cables, much more. Open M-F 10 AM-9PM, Sat 10 AM-7 PM. Buy and sell used gear and have qualified repair facility. ABARIS SYSTEMS, 276 Oriental Pl., Lyndhurst, NJ 07071 (201) 939 0015.

COLLINS EQUIPMENT KWM2A, 75S1, 312B5, 30L1, Hunter Bandit 2000A, dummy load, MFJ Versa Tuner, Speaker Clock, miscellaneous. John Lorenz, WA9ROV, 6027 Southpark, Morton Grove, IL 60053. (312) 965 0722. No collect.

WA9GFR COMMUNICATIONS SOFTWARE. $15.00 disk contains HF VHF/UHF/L Band propagation programs to predict range in miles based on transmitter power, receiver sensitivity, and antenna height & gain. A "must" for designing repeater installations. Also includes Smith Chart impedance matching programs. Commodore-64 or IBM. Lynn Gerig, RR1, Monroeville, IN 46773

ALUMA TOWERS. Crank up with hinged base, house bracket, mast. Mobile van, rooftop, trailer towers. Stack sections. Will take Amateur gear or computers on trade. McClaran Sales, PO Box 2513, Vero Beach, FL 32961. (305) 567 8224

SAT TRAK II A complete advanced self contained satellite tracker with AZ/EL rotor control. Enter Keplerian data once via RS 232 with terminal or computer. Memory for 12 satellites. Accurate. Solid state AZ/EL drive. Available from ADR, PO Box 10184, Sarasota, FL 34230. (813) 378 3410

WANTED—Radio Broadcasting Equipment for rebuilding and parts. Jon, WR4MMV, 98 Woodlake Drive, Charlottesville, VA 22901. Phone (804) 978 1220 or (804) 973-8697

WANTED TO BUY—Schematic or Manual for Heathkit Oscilloscope Model 10-14. Have Apple public domain software. Will trade. Request list. Hubert Testroet, 1305 West 41 Street, Davenport, Iowa 52806.

SMART BATTERY CHARGER for gell-cells or lead acid batteries, by Warren Dion, W1BBH. See June 87QST Magazine for circuit details. Complete kit, nothing else to buy, only $49.95 plus $3.50 s/h. Order #150 KIT. A & A Engineering, 2521 W. LaPalma, Unit K, Anaheim, CA 92801

CODE PROGRAMS. APPLE/C-64. 37 modes. LARESCO, POB 2018, 1200 Ring Road, Calumet City, IL 60409. 1 312 891 3279

IBM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break in buffer, selcalling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS 232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019

MEASURE VSWR, antenna patterns, match circuit impedances from 100 kHz to 2 GHz with portable scalar network analyzers. Write for details. Direct Conversion Technique, 3132 North Lowell Avenue, Chicago, Illinois 60641. (312) 283 1690

CHASSIS, CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

TELEVISION SETS made before 1946, early TV parts, literature wanted for substantial cash. Especially interested in "mirror in the lid" and spinning disc tv's. Finder's fee paid for leads. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521 5280

ENGINEERS request free catalog of Electronics Software. Circuit analysis, filter design, graphics, etc. BV Engineering, 2200 Business Way, Suite 207, Riverside, CA 92501. (714) 781 0252.

NEW AND USED EQUIPMENT. Many hard to find items. Send large SASE to KA5TLG, 4812 Terrace Trail, Fort Worth, Texas 76114

COMMODORE REPAIR. We are the largest/oldest Authorized Service Center in the country. (eg: C64 $39.95). Fast turnaround. Call Toll Free 1 800-642-7634, 800-248-2983, (outside NY) or 914-356 3131. Kasara Inc., 36 Murray Hill Drive, Spring Valley, NY 10977.

TEN TEC. Now shipping new boxed USA made latest factory models, 561 Corsair II, 525D Argosy II, and Century 22 transceivers. RX325 general coverage receiver, model 2510 mode B satellite station, TT920 airband aviation handheld transceiver, Model 229B 2KW antenna tuner, Model 425 Titan 1.5KW linear amplifier, plus accessories and antennas. Also booking orders for Paragon delivery. For best deal write or phone Bill Slep 704 524 7519. SLEP Electronics Company, Highway 441, Otto, NC 28763

DIGITAL AUTOMATIC DISPLAYS for FT 101's, TS 520's (DG-5 clone), Collins, Drake, Swan, Heath and all others. Six 1/2" digits. 5" wide by 1 1/4" high metal cabinet. Reads receive and transmit frequencies. Send $2.00 for information and receive a $30.00 discount. Includes accuracy comparison of the simple "BCD" readouts, found in new radios, against our "Calculating Frequency Counter" readouts. Please be specific. GRAND SYSTEMS, POB 2171, Blaine, Washington 98230

COMMODORE C-128 Radio/Electronics and Engineering Design software. Not available through any other source. Over 65 Design Programs. User Friendly. Send $20.00 for 2 disks or SASE for information to Tri-County Amateur Radio Club c/o KA4ZAY, PO Box 680741, Miami, FL 33168 8741.

WANTED to buy. Schematyic or manual for Heathkit Oscilloscope Model 10-14. Have Apple Public Domain software. Will trade. Request List. Hubert Testroet, 1305 West 41 Street, Davenport, Iowa 52806.

RTTY JOURNAL—Now in our 35th year. Join the circle of RTTY friends from all over the world. Year's subscription to RTTY JOURNAL, $10.00, foreign $15.00. Send to: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

MARCO: Medical Amateur Radio Council, Ltd. operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc) invited to join. Presently over 550 members. For information write MARCO, Box 73's, Acme, PA 15610

HAM LAB PROJECT. Want several pieces HP G 382A variable attenuator. Will consider any repairable condition. K6GOX, PO Box 10, O'Neals, CA 93645 (209) 868 3548 Collect

30 YEARS PROVIDING QSL's. Full color Old Glory. Cartoons. Also Parchment, Golden Eagle and others. Free samples. SASE appreciated. Rusprint, Rt 1, Box 363 HR, Spring Hill, KS 66083.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: *Receiving, transmitting, microwave ... all* types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC. ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

MINNESOTA: December 5. The annual Handi-Ham Winter Hamfest, Eagles Club, Faribault. Registration starts 9 AM. Handi-Ham equipment auction. Dinner at noon. Program follows. License exams. Talk in on 19/79. For information, Don Franz, WØFIT, 1114 Frank Avenue, Albert Lea, MN 56007

INDIANA: SOUTH BEND. January 3. Hamfest Swap & Shop first Sunday after New Year's Day at CENTURY CENTER downtown on US 33 Oneway North between St. Joseph Bank Building and river. Four lane highways to door from all directions. Tables: $5/5 ft. round; $15 8x2.5 rectangular, $20/8 ft. Wall locations. Talk in freq. 52-52, 99-39, 69-09, 34-94, 145.29. K9IXU (219) 233 5307.

WISCONSIN: January 9. The 16th Annual Midwinter Swapfest sponsored by the West Allis Radio Amateur Club. Waukesha County Expo Center Forum, 8 AM to 3 PM. Admission $2.00 advance, $3.00 door. 4' tables $3.00/advance, $4.00 door. Advance deadline January 2. Exams given, dealers welcome, fine food available. For tickets or information SASE to WARAC Swapfest, PO Box 1072, Milwaukee, WI 53201.

MICHIGAN: January 24. The Southfield High School ARC is sponsoring their 20th annual Swap & Shop, Southfield HS, 24657 Lahser, Southfield. Doors open 6 AM for exhibitors, public 8 AM to 3 PM. Admission $3.00. 8' reserved tables $20.00 in advance. Additional reserved tables $10.00 each. All profits go toward Electronic Scholarships and to support Southfield HS ARC. For information, reservations: Robert Younker, Southfield High School, 24675 Lahser, Southfield, MI 48034

HAM EXAMS: The MIT UHF Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday December 23, 7 PM, MIT Room 1-150, 77 Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 646-1641. Exam fee $4.25. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770 4023